Report No. 8

THIRD ANNUAL REPORT

OF THE

SCIENTIFIC AND INDUSTRIAL RESEARCH COUNCIL OF ALBERTA

1922

PRINTED BY ORDER OF THE LEGISLATIVE ASSEMBLY

EDMONTON:
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1923.

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University of Alberta,

Edmonton, Alberta,

February 14th, 1923.

Hon. Herbert Greenfield,

Provincial Secretary,

Edmonton, Alta.

Sir:—

Under instruction from the Scientific and Industrial Research Council of Alberta, I herewith submit their Third Annual Report. This covers the work done under their direction during the year ending December 31st, 1922.

Respectfully submitted,

Edgar Stansfield,

Honorary Secretary.

THIRD ANNUAL REPORT OF THE SCIENTIFIC AND INDUSTRIAL RESEARCH COUNCIL OF ALBERTA

PERSONNEL AND MEETINGS OF THE COUNCIL

No changes occurred in the personnel of the Council during the year. This is as given below:—

HON. HERBERT GREENFIELD, Provincial Secretary, Chairman;
H. M. TORY, President, University of Alberta;
J. T. STIRLING, Chief Inspector of Mines, Province of Alberta;
J. A. ALLAN, Geologist, University of Alberta;
N. C. PITCHER, Mining Engineer, University of Alberta;
EDGAR STANSFIELD, Honorary Secretary.

Six meetings of the Council were held during the year, with a full attendance at five of them.

STAFF

The following changes have been made during the year:—

F. C. Smith became Laboratory Assistant on February 10th, and left on May 23rd.

H. D. Moon took over this work on May 24th.

S. M. Blair commenced work as Assistant Engineer in the Road Materials Division on November 21st.

The permanent staff on December 31st, 1922, was as follows:—

EDGAR STANSFIELD, Research Engineer, *Fuels*;
K. A. CLARK, Research Engineer, *Road Materials*;
R. T. HOLLIES, Assistant Research Engineer, *Fuels;*
S. M. BLAIR, Assistant Engineer, *Road Materials*;
J. B. COGHILL, Recording Secretary;
H. D. MOON, Laboratory Assistant.

In addition to the above, Professors J. A. Allan and N. C. Pitcher, of the University of Alberta, Members of the Council, are in permanent charge of the Council's research work in Geology and in Mining Engineering, respectively.

Other members of the University Staff, notably Professors Kelso, Robb, Wilson, A. E. Cameron and Morrison, are giving assistance from time to time, and two Demonstrators in Mining Engineering, J. W. Lewis, during the first five months of the year, and N. H. Atkinson, during the last three months of the year, gave much of their time to the Council's research on fuels.

In the Geological Division, Dr. Allan was assisted by the following temporary members of the staff, both in the field work and in the preparation of reports:—

R. L. RUTHERFORD, Field Geologist in charge of survey work in the Saunders Creek and Nordegg coal basins;

J. O. G. SANDERSON, Field Assistant on the same survey party;

A. E. CAMERON, Field Geologist with the survey of the north shore of Lake Athabaska;

VERA V. STOVER acted as Geological Office Assistant, and looked after correspondence and the compilation of information on the mineral resources of Alberta.

In addition to the above, four other men held subordinate positions in the survey parties in the Foothills.

ORGANIZATION

In the organization of the University of Alberta the staff of the Research Council constitutes the Industrial Research Department, and the Research Council's laboratories are referred to as the Industrial Research Laboratories.

In the organization of the Provincial Government the work of the Research Council is attached to the Department of the Provincial Secretary.

LABORATORIES AND EQUIPMENT

The laboratory accommodation granted by the Board of Governors of the University for the work of the Research Council, and also the general facilities of the University made available for such work, were outlined in last year's report. During the year further work-benches have been installed in the laboratories of the Industrial Research Department, the coal-briquetting equipment has been set up in the Crushing Room of the Mining Engineering Department, and some work on the separation of bituminous sands has also been carried out in the laboratory of the latter department.

The principal items of new equipment acquired during the year are as follows:—

Coal briquetting plant, Sturtevant coal crusher-sampler, four recording thermometers, barometer, three chemical balances, autoclave, universal mixing machine, Dulin-Rotarex asphalt extraction apparatus and a motor-driven Wing "Scruplex" fan acquired by purchase;

Also, calorimeter for use with hot-air furnaces, portable coal crusher-sampler, riffle sampler, coal drier, set of centrifuge cups, automatic gas sampler, gas meter prover and many pieces of apparatus for use in the bituminous sand separation plant, all of which were designed and largely constructed at the University.

A large Jacobsen & Schraeder model screen for coal-screening tests was purchased from the Manitoba Bridge & Iron Works, but was not delivered in time to be set up during the year. Further progress was made with the Research Reference Library, for which suitable accommodation has now been provided in Room 148 in the Arts Building.

FUELS

The work on fuels described in previous reports has been continued, and new work commenced. Three carload samples of coal have been received and tested, and storage work is still in progress. The number of carloads received is smaller than that for the previous year, but it should be pointed out that during this year tests were still in progress on all the ten samples previously received. Three of these were completed during the year, and three new samples received, as stated above, so that storage tests on ten carload samples will be carried forward into 1923.

The results of prolonged storage show that the new methods adopted the year before were a distinct improvement on the earlier methods. A new laboratory method devised this year for testing coals before and after storage has proved unexpectedly successful for determining the loss of heat value of the coal during storage.

Screening tests and boiler trials have been carried out as before. Tests on the suitability of the different Alberta coals for blacksmith use have been inaugurated, and are to be continued on subsequent carload samples. Systematic tests with house-heating furnaces have been carried on through much of the year, and the methods and equipment employed have been considerably improved. In particular, a calorimeter has been devised and constructed for measuring the efficiency of operation of a hot-air furnace. The installation of recording thermometers and other apparatus has enabled more prolonged and complete trials to be made than heretofore, and with a smaller staff engaged in the work.

Further study has been made of the methods of coal sampling, both in the mine and in the laboratory. A power-driven crusher-sampler has been added to the laboratory equipment, and also a riffle sampler, whilst a portable crusher-sampler has been designed, constructed and tested. This latter apparatus is intended for use by mine inspectors at the mines.

Tests have been made with the experimental carbonizer for lignites, but the time available did not permit as much progress to be made with this work as had been hoped. One big step in advance was made, when it was shown that raw lignites could be satisfactorily dried and carbonized in one process.

The briquetting press and equipment ordered from England in February was not delivered until October. The design, construction and erection of the necessary foundations and lay out, etc., including shafting, pulley, etc., was not completed until December, so that only a few preliminary runs were made with the press during the year. The equipment appears to be very satisfactory for research investigation, and work will be carried on as rapidly as possible during the coming year.

It may be of interest to point out, as illustrating the work done on fuels in the chemical laboratories, that some 70 samples have to be taken, prepared and tested in the regular routine work on a single carload of domestic coal. Special work on the coal largely increases this number.

A detailed account of all this work on fuels is given as an appendix.

GEOLOGY

The geological work for the Council was carried on in conjunction with the Department of Geology. The demand for information on various phases of the mineral resources of Alberta increased during the year. The requests were of a varied character, including the technology of ceramics, water supply, pleasure resorts, trail facilities in certain districts, oil reservoirs, helium springs, meteorites, etc. During the year, 552 letters were received, and 561 were written. Many of these dealt with grossly exaggerated reports appearing in the press from time to time relative to rich deposits of minerals. Four and a half months were spent on field work. Two field parties were directed by J. A. Allan, one in the foothills north of the North Saskatchewan river, and one for a short time on the north shore of lake Athabaska. A short summary of the field work is given in the appendix, and fuller details of these field surveys make up the Fourth Annual Report on the Mineral Resources of Alberta, 1922.

MUSEUM

An exhibit of minerals from Alberta and adjoining territory, and manufactured products from these minerals, formerly maintained by the Research Council in the Mining Engineering Building, has been transferred to the top floor of the Arts Building, to Room 312, close to the Geological Museum. The principal addition to this exhibit during the year was a suite of iron-bearing rocks from lake Athabaska, from the district described in Part II. of the Fourth Annual Report on the Mineral Resources of Alberta, 1922.

The complete rock core from the salt well drilled by the Alberta Government at Fort McMurray in 1920 was brought down from the well site, and has been arranged in open exhibit cases in such a way that any portion of the core can be seen and studied with convenience.

ROAD MATERIALS

The work on road materials has been directed towards the development of a type of rural road construction which should be generally applicable to road building conditions in the prairies. As stone and gravel are not as a rule available, the attempt is being made to employ asphalt obtained from the bituminous sands of northern Alberta as the stabilizing material for such roads. The work of the year has been: firstly, to devise a method of extracting the asphalt from the bituminous sands; and, secondly, to study the stabilizing action of this extracted asphalt when incorporated into prairie roads. A method of extracting the asphalt has been worked out which appears to be satisfactory. Good laboratory results have also been obtained in producing stable bituminized soil mixtures. A further activity of the year has been a study, in co-operation with the City Engineer's Department of the City of Edmonton, on the practical suitability of crude bituminous sands for city pavement construction. An account of the above work is given in the appendix.

SALT AT McMURRAY

Prospecting for salt at McMurray was undertaken by the Provincial Government in 1919. The first well, drilled with a rotary calyx drill, was completed in 1920. A commercial bed of salt was encountered at about 648 feet from the surface. The results of this prospecting are described by J. A. Allan in the Second Annual Report on the Mineral Resources of Alberta, 1921. Mr. N. C. Pitcher made a trip to McMurray early in June and examined the drilling equipment on hand.

With the completion of the Alberta & Great Waterways Railway to Waterways, on Clearwater river, six miles from McMurray, it was decided to prospect for salt close to the railway by drilling another well. A well site was chosen by J. A. Allan at the junction of Deep creek and Clearwater river, within a few hundred yards of the railway, and drilling began in October, 1922. Drilling operations were discontinued during the severe winter weather, but will be resumed in the spring.

FOREST PRODUCTS

The collecting of existing data pertaining to Alberta forest resources was continued throughout the year.

It is hoped that compilation and indexing may be started in 1923, and that a beginning may be made of a series of explorations and tests of timbers from the more important areas which are the present source of mine timbers.

The proposed compilation and indexing may take the form of a critical bibliography of published information, and be referred to a specially prepared control map of the Province. This control map may be supplemented with smaller detailed maps of selected areas.

COAL SAMPLES AND ANALYSES

Three carload samples have been received during the year These samples were taken under the supervision of the district inspectors of mines to represent the regular output of the mine. In addition to the large samples, the district inspectors of mines of the province have taken nineteen coal samples from four different mines. Ten of the latter samples have been analyzed for the provincial Mines Branch by Mr. J. A. Kelso, Provincial Analyst. The remainder were analyzed by Mr. R. T. Hollies in the Department's laboratories. As a matter of convenience, and by arrangement with Mr. J. T. Stirling, Chief Inspector of Mines, all these analyses are given in the appendix. Some details of the methods of sampling and the significance of the results are also given. A compilation of all available analyses of Alberta coals has been commenced. It is hoped, when this is completed, to calculate the average analyses of the coal from each of the mines in the province, such calculation to be based on comparable and reliable analyses. Meanwhile an interim statement has been prepared and included in the appendix to this report, giving a typical analysis of coal from each of the principal coal areas of the province.

ACKNOWLEDGMENTS

The Blue Diamond Coal Company, the North American Collieries, and the Big Valley Collieries have each contributed a carload of coal during the year. Several other offers of coal are still outstanding for delivery when the work of the laboratory permits. The Council wishes to express their appreciation of the support they are receiving from the operators in this and other ways.

The domestic heating furnaces on which tests are being made were contributed by The Gurney Foundry Co., Ltd., The Gravity Stoker Furnace Co., Ltd., The McClary Manufacturing Co., Ltd., and Mr. R. W. King, of Toronto, Ont.

FUELS

By N. C. Pitcher, E. Stansfield, R. T. Hollies, J. W. Lewis and N. H. Atkinson (to which is added a Report on Boiler Trials by C. A. Robb)

The work described below is a continuation of that outlined in previous reports, but the scope has steadily increased.

Coals Tested

Three carload samples of run of mine coal were received during the year for screening, storage, boiler and other tests. The coal was in each case donated by the mine operator. A list of coals, classified under their respective areas, follows:—

Jasper Park Area:—

Blue Diamond Coal Co., Ltd., Brule, Alta.

Drumheller Area:—

North American Collieries, Ltd., Monarch Mine, Nacmine, Alta.

Big Valley, Trochu, Three Hills, Carbon Area:—

Big Valley Collieries, Ltd., Big Valley, Alta.

Sampling

The two problems of sampling at the mine and sampling in the laboratory have been studied during the year. In consequence of some sampling tests made at Brule at the end of 1921, but not completed until the current year, a committee, which included representatives from the Mines Branch and the Research Council, together with the Provincial Analyst, made a careful study of the question of sampling as applied to bituminous mines. This committee decided upon certain changes in the procedure of sampling, the principal of which involved the use by mine inspectors of a portable crusher-sampler in place of coning and quartering for the reduction of mine samples. Such a sampler was afterwards designed by E. Stansfield and R. T. Hollies, and constructed in the University workshops. This apparatus, which is represented in Figure 1 (see next page), is made in such a way as to be readily taken to pieces and packed in the travelling case provided. A riffle sampler outfit, brush, shovel and all necessary tools and spares were also packed into the same box. The crusher is designed to first crush the coal to about ½-in. size, and, simultaneously, to cut out one quarter. This quarter is then reground to ¼-in. size in the same crusher after a simple adjustment, and again simultaneously quartered. The final sample can then be riffled down to a

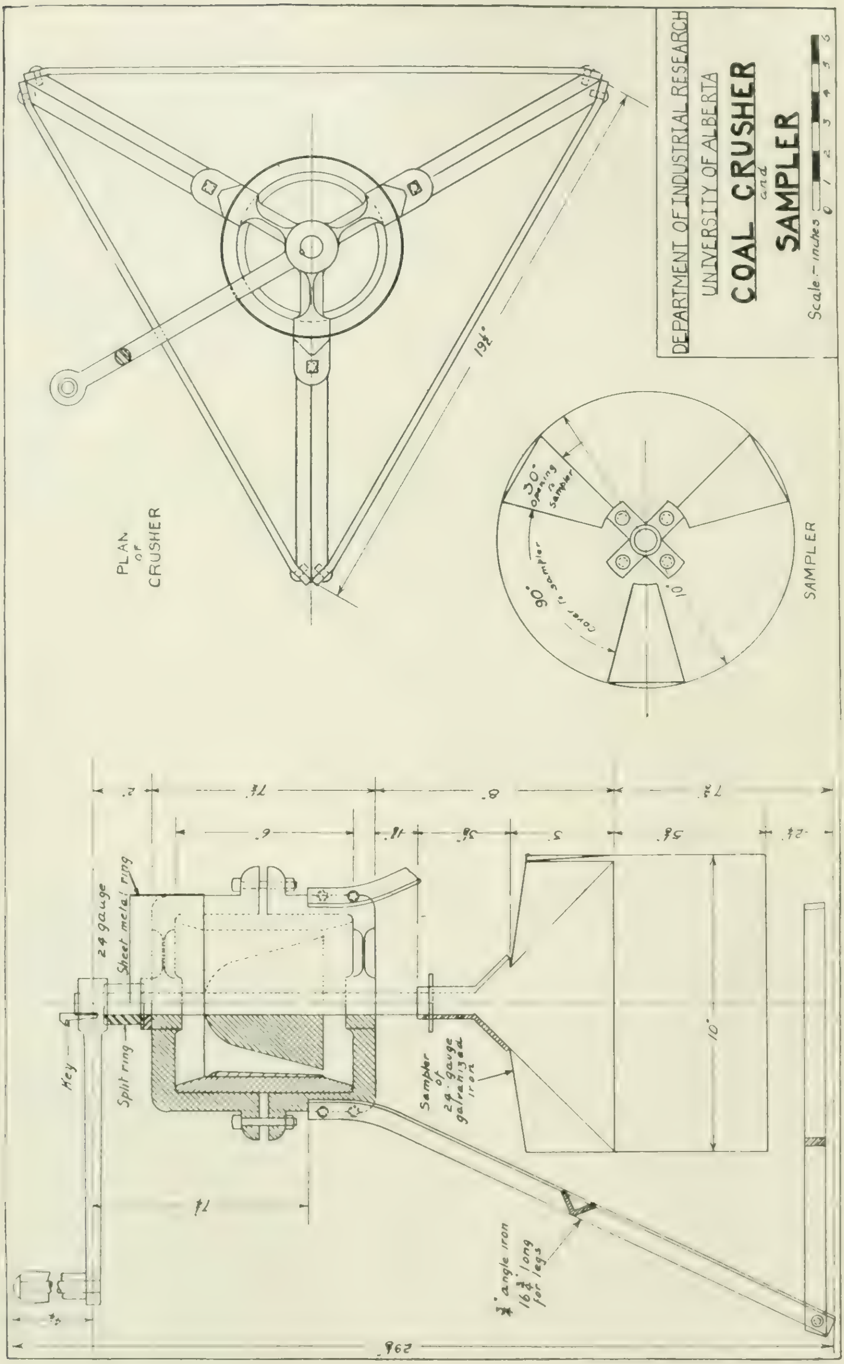

Fig. 1.—Portable Sampler Crusher.

suitable amount to fill a quart sealer. This apparatus was tested by screen and chemical analyses of both sample and discard, and it was found that with reasonable care the discrepancy between the percentage of ash in sample and in discard should not exceed 0.2 per cent.

In November, 1922, the above equipment was used by Inspector of Mines W. Shaw, E. Stansfield and R. T. Hollies in some tests at the Penn Mine to ascertain the accuracy with which mine channel samples represented the commercial output of domestic mines. The channel samples were taken as usual, but in addition samples were taken of each of the commercial products of the mine. The average ash content of the commercial output of the mine was calculated from the figures given as to percentage production and chemical analysis of each of the sizes of coal sold. This was found to be identically the same as the average ash content of the channel samples.

Mr. Shaw took similar samples later at the Lakeside Collieries, Wabamun, and the results obtained in this case showed 7.77 per cent. ash for the output and 7.37 per cent. for the average of the channel samples.

These results are better than could be hoped for regularly, and are a good indication that the channel samples, as taken, do give a close approximation to the regular output of the mine.

It is recognized that carload samples give a better representation of the output of the mines, and it is hoped ultimately to obtain and test such samples, not only from every area, but also from each of the principal mines in these areas. It is clear, however, that such work will take long to complete, and that channel samples must play an important part meanwhile in evaluating the coal output of the province.

In the laboratory, the method of coning and quartering has been entirely superseded by the use of a Sturtevant crusher-sampler, followed by an Allis-Chalmers sample grinder and a modified Jones riffle. The Sturtevant crusher is used to reduce the coal from egg to ½-in. size, and it automatically cuts out a 5, 10 or 15 per cent. sample, as desired, during the process. The sample grinder reduces the coal to about ⅛-in. size and cuts it in half. Further reduction of quantity is done by the riffle, after which the sample is air-dried and ground in an Abbe porcelain ball mill. The new method is far more rapid, and at least as accurate as the one superseded.

Analyses

One change was made during the year in the methods employed for the proximate analysis of coal. Thus a modified method for the determination of volatile matter in sub-bituminous and lignitic coals has been devised, tested and adopted. The regular method of the A. S. T. M. calls for a preliminary heating for such coals for five minutes over a gradually increasing flame, followed by six minutes heating at the full temperature employed for other coals. This procedure is rendered necessary by the fact that when a coal of high volatile-matter content is heated suddenly, the rapid rush of gas carries with it many solid particles, and an erroneous result

is obtained. In the new modification the preliminary heating described above is standardized as follows, the rest of the treatment being as before:—

The coal is weighed out as usual into a crucible which is then covered and placed on a cold scorifier of 3-in. diameter. The scorifier is then placed in an electric muffle furnace heated to 725°C., ±25°, and left there for five minutes. The hot crucible is then removed, and immediately heated as usual for six minutes in a suitable electric furnace or over a gas flame regulated to a temperature of 950°C., ±20°. The crucible is then cooled in a desiccator, and the loss in weight determined.

Insertion of the cold scorifier between the bottom of the crucible and the hot floor of the muffle reduces the rate of heating and causes the coal to be heated mainly from above. The effect is to drive off the volatile matter as before, but without risk of loss of solid particles. Careful tests show that more closely concordant results can be obtained than heretofore, and with less attention from the analyst. The new method, therefore, appears to be both quicker and better.

SCREENING

This work is a continuation of that briefly described in the two previous reports. The procedure followed was given in the Second Annual Report of the Council, pages 15 to 23. The car of coal is placed on the railway siding near the University and unloaded by means of carts. About thirteen tons are delivered to the Mining Engineering Laboratories, and the remainder to the University power house. The former portion is used for screening, storage and other tests, and the latter for boiler trials. The sample for chemical analysis is obtained to represent the whole consignment by removing a shovelful at regular intervals as the carts are unloaded. The ton of coal thus obtained is crushed and quartered in the regular equipment of the Department.

Table I. shows, for the mines tested during the year, the percentage of each size found in the run of mine coal after it had been delivered at the University. It should be noted that the percentages of lump and fines in any consignment must depend somewhat on the handling it received in transit as well as on its friability and its condition as it left the mine. The results, however, are clearly indicative of the nature of the coal and the condition in which it might be expected to arrive at the consumer.

TABLE I.

Name of Size	SCREEN SIZES Diameter of Circular Perforations		PERCENTAGE OF SIZES IN RUN OF MINE		
	Through	Over	Blue Diamond	Monarch	Big Valley*
Lump	....	3 "	4.3	58.6	57.4
Egg	3 "	1½"	8.3	19.3	25.9
Nut	1½"	¾"	11.1	8.8	9.6
Pea	¾"	¼"	26.7	7.8	4.6
Dust	¼"	....	49.6	5.5	2.5
Slack	¾"	....	76.3	13.3	7.1
Nut Slack	1½"	....	87.4	22.1	16.7
Screened Coal	....	1½"	12.6	77.9	83.3

Table II. shows the percentage of ash found in each of the original run of mine coal samples, as well as in each sized product therefrom. The percentages are reduced to the dry coal basis.

TABLE II.

Standard Size	ASH PERCENTAGE (DRY BASIS) In R.O.M. and Standard Sizes of the Coals Named		
	Blue Diamond	Monarch	Big Valley*
R.O.M.	17.3	15.7	11.8
Lump	18.3	16.9	10.8
Egg	23.2	17.3	14.3
Nut	24.9	15.0	17.5
Pea	19.8	15.7	15.1
Dust	17.2	13.2	19.4

Equivalency tests were carried out on another portion of the original coal. These tests were to determine the bar screen spacings which must be employd with any coal to get the same percentage results, when the run of mine is screened, as those obtained with the plate screens having circular perforations. Table III. shows clearly the principal results obtained, averaged for those districts from which coals have been tested.

TABLE III.

Diameter of Plate Perforations	EQUIVALENT SPACING FOR BAR SCREENS— For the Coal Areas Named							
	Mountain Park	Jasper Park	Yellow Head Pass	Drumheller	Big Valley, &c.	Pembina-Wabamun	Camrose-Battle River	Edmonton-Clover Bar
	Measurements given are in sixteenths of an inch							
3 Inches	29	28	28	26	25	32	26	33
2 "	16	16	16	18	18	21	16	....
1-½ "	12	12	12	14	12	16	12	12
1 "	8	8	8	9	8	11	8	....
¾ "	6	6	6	7	6	8	6	8
¼ "	3	3	3	3	3	3	3	3

*This sample of coal was screened over a 1½-in. bar screen as it was loaded into the car, this being the usual practice at this mine for R.O.M. shipments.

STORAGE

Work on the effect of different methods of storage on coals from the different fields has been conducted as before. Samples stored for various periods have been brought in from the storage ground, re-screened and re-analyzed, as listed below:—

Domestic coals: 30 samples after one month, 30 after six months, 16 after 12 months, and 15 after 24 months' storage: coals tested were, Dobell, Foothills, Drumheller, Pembina, Humberstone, Twin City and Big Valley.

Bituminous coals: one after one month, three after six months, three after twelve months, and one after 24 months' storage: coals tested were, Blue Diamond, Mountain Park, Pocahontas and Cadomin.

The earlier results obtained were, to a certain extent, disappointing, as variations due to extraneous causes largely confused and masked changes in the coal due to storage. This was especially the case with respect to the chemical changes, as the physical changes are more marked. The matter was first considered in October, 1921, mainly in connection with lack of storage facilities in the pit and shed. To increase the latter, it was decided to store all the samples in pit and shed in jute sacks. This, it was considered, would have the extra advantages of cutting down the work involved and of increasing its accuracy. Later on, when the 1921 results were under consideration, it was decided that open storage methods must also be modified. Since the middle of February, 1922, therefore, all outdoor samples have been stored in large garbage cans. In the present method, the total quantity set aside for storage is carefully divided in the laboratory into the requisite number of portions, as nearly as possible identical, before the coal is sent out at all, as at this stage it can be divided fairly accurately. These portions are placed in sack or can as above and weighed. At the end of each storage period the assigned sack or can of coal is brought in, untouched, then weighed, and the whole amount screened and sampled. It is early as yet to say whether these methods will give the necessary accuracy, but it is already clear that they are a great improvement on the former ones. Moreover, one assistant can now do the screening and sampling on a storage lot in less time than was previously taken by two men.

Table IV. shows the results obtained with respect to the disintegration of domestic coals.

TABLE IV.

Kind of Coal and Date First Stored	Size of Coal	PERCENTAGE BREAKAGE LOSSES DUE TO WEATHERING after storage for											
		One month in			Six months in			12 months in			24 months in		
		Open	Pit	Shed	Open	Pit	Shed	Open	Pit	Shed	Open	Pit	Shed
Foothills	Lump	0	0	15	10	2	0	0	1	10			
	Egg	20	0	0	25	1	5	20	10	10			
Dec. 1921	Nut	15	15	5	30	10	10	30	10	10			
	Pea	5	5	2	10	3	5	10	2	4			
Monarch	Lump	0	10	4	10	10	15						
	Egg	5	3	2	20	10	10						
Feb. 1922	Nut	3	5	0	10	4	4						
	Pea	0	0	0	0	0	0						
Big Valley	Lump	4	5	2									
	Egg	3	0	0									
Oct. 1922	Nut	3	4	3									
	Pea	0	0	0									
Pembina	Lump	55	45	30	45	40	25	45	45	25			
	Egg	50	25	35	50	25	30	40	35	25			
Mar. 1921	Nut	35	20	20	30	25	25	50	20	25			
	Pea	10	5	10	10	5	10	15	5	5			
Dobell	Lump	30	25	30	25	20	25	40	40	30			
	Egg	....	40	20	....	30	20	....	35	20			
Sept. 1921	Nut	....	20	30	....	25	25	....	25	35			
	Pea	....	5	5	....	3	5	....	5	5			
Clover Bar	Lump	30	20	15	50	20	20	45	40	35	60	30	45
	Egg	0	5	2	40	15	30	40	20	20	45	15	25
Feb. 1921	Nut	2	10	5	30	15	30	40	15	10	50	10	10
	Pea	1	5	5	10	0	5	20	5	10	15	3	5

It is fully recognized that present work on storage is only of a preliminary nature. The coals can not be stored in large enough quantities or under sufficiently uniform conditions to enable definite conclusions to be drawn with regard to their commercial storage. Valuable information has, however, been obtained, and it is hoped that when this preliminary work has been completed large scale work can be carried out at the mine-heads and at the distribution centres without the costly mistakes that otherwise inevitably would have been made.

DOMESTIC FURNACES

Four domestic furnaces were tested during the year. These furnaces were illustrated and described in last year's report, pages 27 to 29. The tests were completed on one furnace, and a full report submitted to the inventor. Further tests have yet to be made on the other three.

Preliminary work on methods of testing domestic heaters was commenced in 1921, and further developed during 1922. The equipment for these tests was increased by the purchase of three single and one duplex recording thermometers, and by the design and construction of a gas sampler and an air calorimeter. Systematic tests were run on these furnaces, as follows: Gurney hot-water furnace, 9 tests with a total duration of 696 hours; Allan hot-water furnace, one test with a duration of 120 hours; Sunshine hot-air furnace, 9

tests with a duration of 397 hours; and King hot-air furnace, 8 tests with a duration of 911 hours. The tests were made with the following objects in view: (1) to determine the practicability of the furnace for use under ordinary domestic conditions with different types and sizes of Alberta coals; (2) to ascertain what improvements, if any, might be suggested for the furnace; (3) to test the merits of any available alternative equipment. It should be noted that the performance and efficiency of the furnaces were tested under the most favorable conditions of firing, adjustments and attention which could be expected for a domestic heater at the hands of the average intelligent householder. No effort was made to determine the maximum efficiency possible with constant attention and adjustment such as could not be expected in regular use.

In general, the furnaces were cleaned, the ashes shaken down, and fresh coal fired, three times a day, usually at 8 a.m., 3 p.m. and 10 p.m. Any adjustments of draft found necessary at the firing period were completed within one-half to three-quarters of an hour after firing. The firing and draft adjustments were arranged to give a steady heat throughout the twenty-four hours. The coal consumptions were varied in different tests within the normal limits of each furnace.

Hot-water heaters are comparatively easy to test. The weight of water sent through the furnace can be easily determined by means of a calibrated water meter, and the inlet and outlet temperatures found by suitable thermometers. The weights of coal fired and ash removed can be noted, and samples analyzed. The temperature of the flue gas can also be determined and samples taken throughout a complete firing cycle and analyzed. Full records can also be kept of the conditions of the fire, adjustments of draft, clinker trouble (if any), etc. If ordinary thermometers are used, these must be read at frequent and regular intervals, and continuous shifts of observers are required. With recording thermometers one observer can carry out a complete trial. A percentage efficiency of the furnace can be calculated from the data collected as above, and a general statement may be prepared as to the performance of the furnace under the particular conditions of the test.

Hot-air furnaces are more difficult to test, as it is hard to measure the quantity of air passed through the furnace casing, and thus heated. It was originally intended to measure this by means of air-boxes and sensitive pressure gauges, and the necessary apparatus was constructed in 1921. Early in 1922, however, the alternative use of a calorimeter was suggested by E. Stansfield. A suitable apparatus was designed in collaboration with R. T. Hollies and was constructed in the University workshops. This calorimeter is used to measure the total heat leaving the furnace in the air flow, rather than to measure the volume of such air, although this volume is subsequently calculated from the data collected. Figure 2 (see next page) is a vertical section of the calorimeter.

The operation of this air calorimeter is as follows:—It is connected to the top of the furnace casing so as to receive all the air heated in the casing from the furnace to be tested. This air is thoroughly mixed on entering the calorimeter by baffles A, and its temperature measured by means of a recording thermometer A1. The baffles are insulated with asbestos board to protect the thermo-

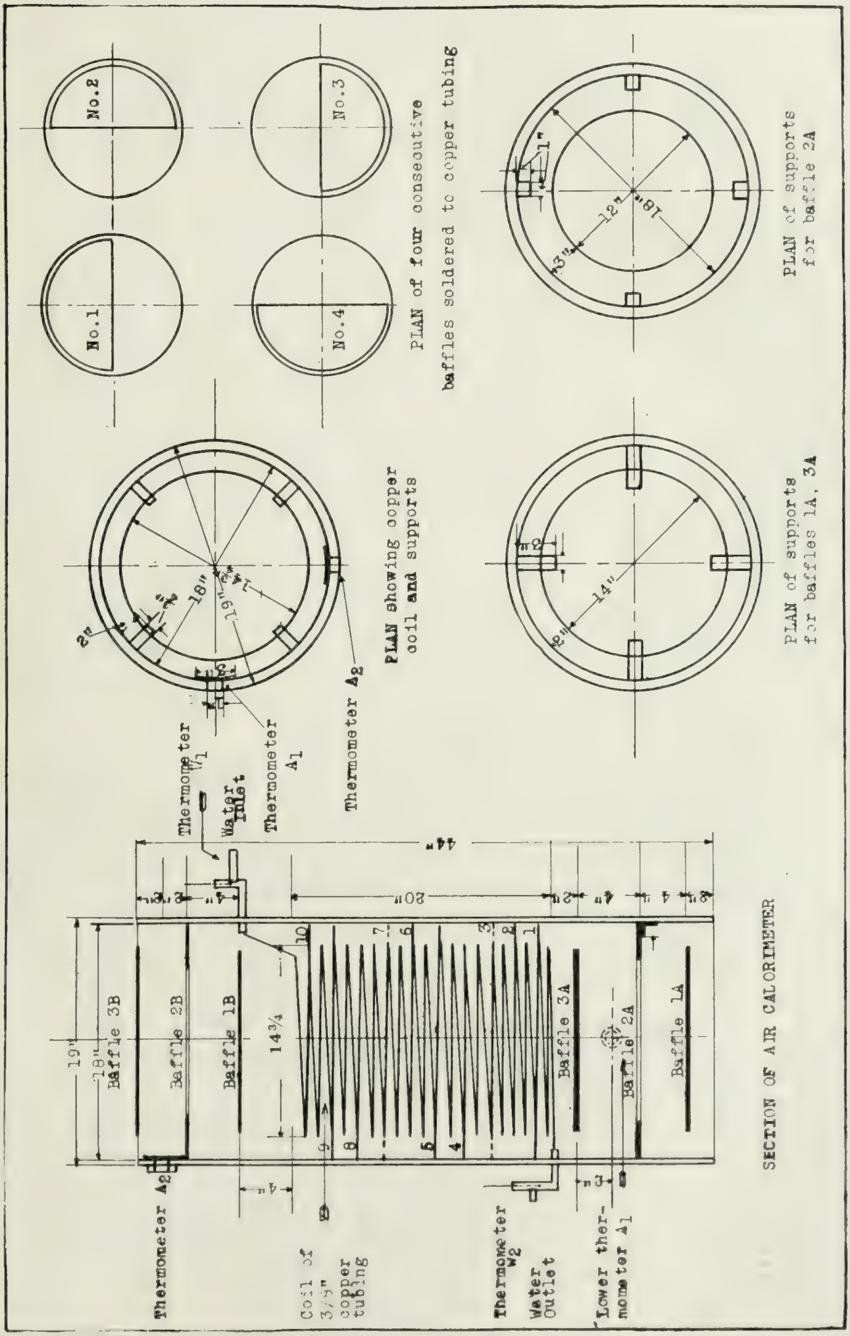

Figure 2.—Sketch Diagram of Air Calorimeter.

meter from heat radiated from the furnace castings. A metered flow of water has its temperature taken where it enters the calorimeter at W1. It flows downward through a ⅜″ copper coil, is warmed by the ascending current of hot air, and passes out at W2, where its temperature is recorded. In later work the water current was reversd. The rising air is given a spiral course past the copper coil by suitably placed copper baffles. These are soldered to the copper coil, and further serve to absorb heat from the air and transmit it to the water flowing through the coil. The partially cooled air leaving the coil is remixed by baffles B, and its temperature recorded by a thermometer A2. The temperature of the furnace room where the air enters the furnace casing is also noted.

The quantity of heat gained by the water in passing through the calorimeter can be easily calculated from recorded observations. This heat gained is assumed to be equal to that lost by the air current in its upward passage through the calorimeter; and to bear, consequently, the same relation to the heat transmitted to the air from the furnace that the drop in temperature in passing through the calorimeter does to its rise in temperature in passing through the furnace. Thus the heat transmitted to the air from the furnace can be deduced from the observations, and the efficiency of the furnace calculated.

It was found that, using this calorimeter, one observer could carry out a long-duration test on a hot-air furnace almost as easily as on a hot-water furnace, although the subsequent calculations take considerably longer. In some tests with hot-air furnaces a 1/10 h.p. electric fan is connected to the lower part of the furnace casing in order to ascertain the increase of efficiency to be expected from an increase of air circulation through the casing.

Gurney Hot-Water Furnace.—This furnace is a No. 908 cottage boiler, with a rectangular firebox measuring 15-in. by 30-in., rocking grates, and a push-nipple section boiler. The furnace, so far, has been found to burn Clover Bar seam egg and lump successfully under ordinary domestic conditions with an efficiency of 44 to 48 per cent. An insulating covering put on the furnace did not materially increase the amount of heat absorbed by the hot-water system. The alternate method of firing was only a slight improvement over the ordinary method. This was shown by a reduction in the combustible loss with the ashes, although the over all efficiency was nearly the same for both methods. The furnace was very easy to operate, and its efficiency varied little with rates of firing ranging from 7 to 15 lbs. of coal per hour (2½ to 5 lbs. of coal per hour per square foot of grate area). Flue gas analyses were only taken on the last test run. The average carbon dioxide for this test was close to 10 per cent., the carbon monoxide was 0.8 per cent., and the oxygen, 8.5 per cent. The gas samples were each taken over a complete firing cycle, and thus include the inevitable dilution of the flue gas with air during firing and cleaning periods. Many more tests are yet to be run on this furnace.

Allan Furnace.—This furnace is a Model "A," gravity feed furnace, patented February 13th, 1917. Tests run on this furnace include one of five days, one of two days, and several from six to

eight hours. The arrangement of the grates and facilities for removing the ashes are not adapted for simple operation. No flue gas samples were taken in these tests, but combustion must have been good, as in the longest test an efficiency of 59 per cent. was recorded. Many more tests would have to be run on this furnace to prove its efficiency, but as there is now on the market a new model for which many advantages are claimed, it appears useless to continue tests on the obsolete type.

Sunshine Hot-Air Furnace.—This is a McClary "Sunshine", No. 91, with the trade name "Sofco." It has a 19-in. firepot. The furnace so far has been found to burn Clover Bar seam lump and egg coal successfully under ordinary domestic conditions, and to burn slack coal from the Clover Bar seam with but slight difficulty with the aid of the G. R. Pratt brick arch. The furnace is easy to operate, and the three separate shaking grates make it possible to clean the fire without much loss of combustible with the ashes. The number of drafts and dampers provided permit a ready control of the fire, although when the fire is burning too briskly it is somewhat difficult to check. It is not yet possible to give reliable data on the efficiency of this furnace, as the air calorimeter proved too small for satisfactory operation. A larger one will have to be built, or other changes made. Tests are to be made to show the value of the air-blast ring around the top of the firepot casting. Further tests also will be made to show the possibilities of this furnace for burning cheaper grades of fuel.

King Hot-Air Furnace.—This furnace consists of a box stove (see Fig. 3) enclosed in a large outer casing (not shown in the sketch). The grate is divided into two parts: a non-movable, non-perforated deadplate (A), and an open shaking grate (B). A reflection plate (C) serves to reflect radiant heat from the fire on the open grates (B) on to the freshly fired coal on deadplate (A). Small holes in the sides and back of the furnace act as air ports to admit air over the grates. The firing door at (E) and the ash pit door at (D) are provided with adjustable disc dampers to admit air above and below the fire, respectively.

To fire fresh fuel properly requires three operations: shaking of grates (B) to remove ashes; removal of all ignited coal on deadplate (A) on to grates (B); firing of green coal on deadplate (A) only. Then heat from fire is partially reflected by (C) on to fresh fuel on (A) to dry it out, distil off gases in coal, and, later, ignite it.

It should be noted that the furnace was an experimental one, designed to test the value of the combustion system, and not designed as a commercial furnace would be to transmit the maximum heat from the fire into the air passing through the casing. The recorded efficiencies are therefore mainly valuable to show the rela-

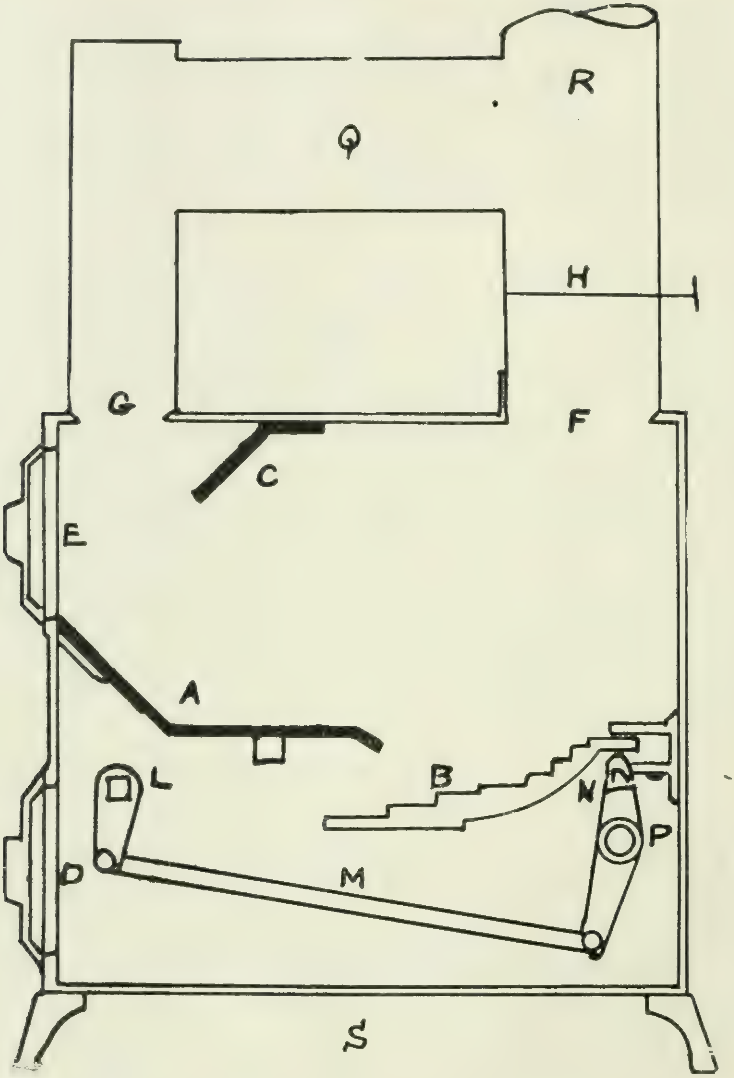

Figure 3.—Sketch Diagram of R. W. King Furnace.

tive merits of the different modifications tested. Eight complete tests were made, each of from four to five days' duration. These showed efficiencies ranging from 18 to 22 per cent., when one poor result is excluded. The furnace has certain good features, and will burn the lower grades of coal, but it requires skilled operation to get regular combustion. As a result of the tests certain changes have been recommended, and it is thought that the inventor may be able so to modify the furnace as to largely overcome its faults while retaining its good features.

Smithy Coal Tests

Much of the smithy coal used in the western provinces of Canada is imported from Pennsylvania at high cost. It is probable that Alberta coal might be largely used instead if reliable information were available on the subject. The Industrial Research Department therefore commenced smithy tests on Alberta coals in March, 1922, as part of the regular program on carload samples received for testing. The carload received in November has not yet been tested at the time of writing this report, due to pressure of other work at the end of the year. This test will be included with the 1923 report. The smithy tests are carried out by the University blacksmith under the supervision of R. T. Hollies. The welded pieces made are examined in the testing machine of the Department of Civil Engineering under the direction of Professor R. S. L. Wilson. Before making the tests, the blacksmith uses the coal in question for his regular work until thoroughly familiar with its qualities. The tests made are: (1) Heat test on the time required to bring a standard piece of 1¼-in. rod up to cherry red heat; (2) two lap welds on 3-in. by ½-in. wrought iron; (3) two butt welds, ⅞-in. wrought iron rod on to 3-in. by ½-in. flat wrought iron; (4) two lap welds on ¾-in. octagon steel; (5) making cold chisel from ¾-in. steel. George's Creek Pennsylvania smithy coal was tested as above at the beginning of the series of tests, and will be tested again later in the series. These tests are taken for comparison with those on the Alberta coals.

The results of two tests are shown on the following page, these being included together in Table V. for ease of comparison. At the beginning of each test, 44 lbs. of coal was placed on a small fire, and time noted till fire was ready for use—four minutes in each case. At the end of the test, surplus coal and coke not used was weighed, leaving fire as at beginning of test. When fire got dirty during test, clinker was removed and time noted. Readings were taken on the length of flame at different periods in the test. The effect of the smoke and of the heat radiated from the flame and fire on the comfort of the blacksmith was noted. The total ash and clinker formed during each test was noted. The blacksmith did not know on what

TABLE V.—RESULTS OF SMITHY TESTS ON GEORGE'S CREEK PENNSYLVANIA SMITHY COAL AND ON BLUE DIAMOND COAL FROM BRULE, ALBERTA, BETWEEN MARCH 30TH, AND APRIL 3RD, 1922

No.	Test	Times in fire	Time in minutes	Yield Point	Failure	Remarks
1	**Heat Test:** Time to bring 1¼″ bar to cherry red.					
	Pennsylvania:	1	3			
	Brule:	1	3			
2	**Lap Weld:** 3″x½″ wrought iron.			lbs. per sq. in.	lbs. per sq. in.	No indication of failure in weld. Not a straight pull, as piece failed one side first*.
	Pennsylvania: (1)	3	24			
	(2)	4	20½			
	Average		22½	31,780	40,000	
	Brule: ....(1)	4	17½	34,880	53,440	Straight pull. No indication of failure of weld. Failed at centre first*.
	(2)	4	19½			
	Average		18½			
3	**Butt Weld:** ⅞″ w. i. on to 3″x½″ w. i. 6″ long.			lbs.	lbs.	
	Pennsylvania: (1)		41	22,310	25,600	Failure of weld under very severe test.
	(2)		27			
	Average		34			
	Brule: ....(1)		32			Failure of weld under very severe test.
	(2)		29	20,480	26,210	
	Average		30½			
4	**Lap Weld:** ¾″ octagon steel.				lbs. per sq. in.	Clean break across specimen. No indication of failure of weld.
	Pennsylvania: (1)		33½			
	(2)		20			
	Average		26½		86,000	
	Brule: ....(1)		26		82,000	Clean break across specimen. No indication of failure of weld.
	(2)		17			
	Average		21½			
5	**Making Cold Chisel:** ¾″ octagon steel.					Chipped scale from cast-iron, mild steel and cast steel without chipping or turning
	Pennsylvania:	4	10			
	Brule:	3	10			

*Untreated specimen of 3″x½″ w. i. gave: Yield Point, 29,340 lbs. per sq. in.; Failure, 46,280 lbs. per sq. in. The pull was straight during this test.

NOTE.—In these tests the operations were carried out the same day, first on Pennsylvania coal and then on Brule coal. It is probable that the extra familiarity of the blacksmith with the exact work to be done enabled him to carry out the tests on Brule coal slightly faster than he would have done, had the order been reversed.

Alberta coal he was making the test. Some further details of the trials are given in Table VI.

Table VI.

Kind of Coal	Pennsylvania	Brule
Amount of coal fired.....lbs.	44	44
Coal and coke residue at end of test..... lbs.	8	8½
Clinker removed during test......times	3	3
Ash and clinker residue of whole test..... lbs.	6	7½
Maximum height of flame.......feet	2	2
Effect of heat of flame on blacksmith	Slight	Slight
Proximate Analysis of Coal:		
Moisture.....%	1.2	0.5
Ash.....%	9.6	20.6
Volatile Matter.....%	17.7	17.8
Fixed Carbon.....%	71.5	61.0
Coking qualities of coal.....	Forms fair lump of well fused coke	Forms small, hard lump of caked material, showing little signs of fusion.

Comparison of Coals

Comparison of the heat value of the coal substance of any two coals is often rendered difficult by variations in the ash content of the two samples. Thus, in storage tests, the sample of the stored coal may show a higher calorific value than that of the fresh coal because the former happens to contain less ash, although it is known that the heat value of the coal substance decreases during coal storage. A common method is to compare the heat values, corrected to an ash-and-moisture-free basis by calculation on the assumption that the ash and moisture are quite distinct from the coal and have no calorific value. This, however, does not give very satisfactory results. The following method was developed as the result of an idea of one of the writers that a comparison on a *bone-coal-free basis* might prove better.

The specific gravity of different pieces of the same seam of coal varies with their ash content, the specific gravity rising with increasing ash. There is, therefore, a well-known method of separating clean coal from dirty coal or bone coal by means of a solution of suitable specific gravity. Thus, if a crushed sample of bituminous coal from the Crow's Nest Pass area is placed in a solution of calcium nitrate of, say, 1.5 specific gravity, all the cleaner pieces of coal will float, and the dirty ones will sink. The float and sink may now be collected separately and each washed free from the solution, dried, weighed and analyzed. This process is commonly employed to decide whether any coal could suitably be purified by washing. When testing coal by this method, it is usual to obtain float and sink samples with three or four solutions of specific gravity varying from 1.3 to 1.55. In the course of the present investigation it was found that if the calorific value of each of the samples of float and sink was plotted against its respective ash content (all calorific

value and ash contents being calculated to a dry basis), then all the points lay along a straight line. Moreover, it was found that within the usual limits of experimental accuracy the calorific value, calculated to a dry basis, of all samples of coal from the same seam, when plotted in the same manner with respect to their ash content, fell along the same line. This, however, is only true when all the samples are of the same age. When coal is stored for a prolonged period, a new curve is obtained, and it has been found that comparison of the earlier and later curves gives a far better idea of any change undergone by the coal than can be obtained by the study of the results of the regular analyses.

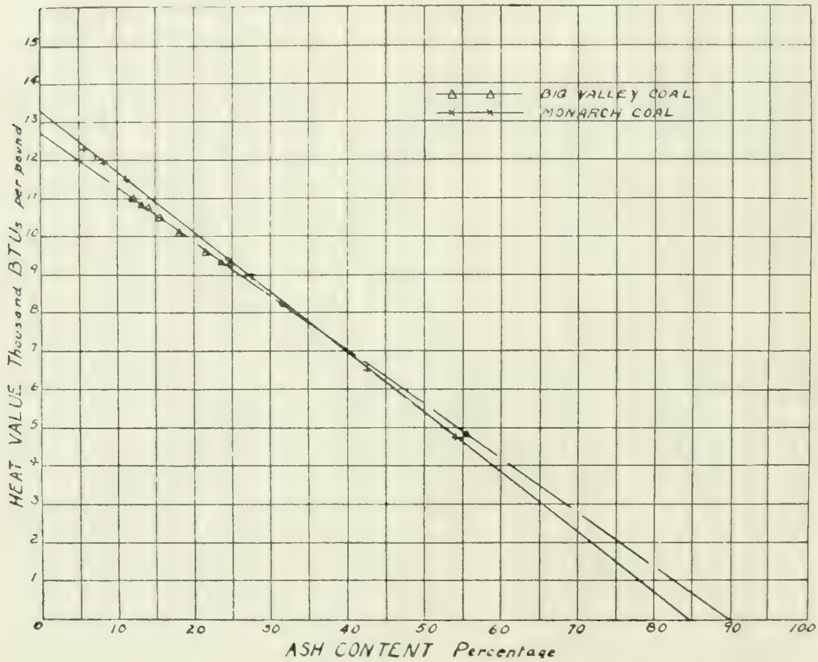

Figure 4.—Comparison Curves, Drumheller and Big Valley Coals.

Figure 4 shows the relation between the heat values and ash content on a moisture-free basis of Monarch coal (Drumheller), and Big Valley coal. Figure 5 shows the effect of oxidation. The upper curve is that for Pembina coal which has been stored for twelve months. The lower curve is that for the same coal, but further oxidized by exposure to air for 90 hours at 110°C.

Many forms of apparatus have been devised to expedite the work of separation of float and sink samples with heavy solutions. The particular apparatus employed in the above work was suggested by E. Stansfield, and constructed in the University workshops. Four brass cylinders were made, 15.2 cm. long, and 3.6 cm. diameter. These were fitted with a cone constriction in the middle which could be closed with a screw-operated cone valve, as shown in Figure 6. The slope of the sides of the cones was made 60° to

insure against particles being retained on their surface and to facilitate removal of the treated sample. A 25-gram sample of coal, crushed to pass a 14-mesh screen, was placed in each cup, with the valve raised clear of its seat, and the cups were filled with the desired solutions. They were then centrifuged for 15 minutes at about 1,150 r.p.m., and the valves then closed. The float from the top half of each cup was washed out on to a suction filter, washed till clean, and dried. The valves were then removed from the cups, and the sink was treated in the same manner. The dried samples were afterwards weighed and analyzed. Calcium nitrate solutions were used for the denser solutions, and calcium chloride for the lighter ones.

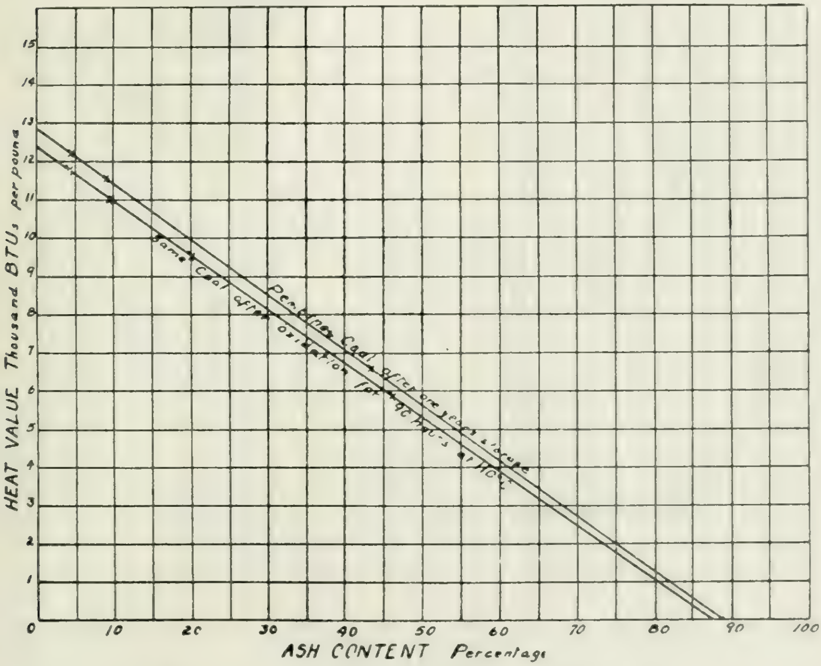

Figure 5.—Comparison Curves, Pembina Coal.

Carbonization

The programme of carbonization which had been proposed for 1922 had to be much curtailed on account of pressure of other work. Nevertheless progress was made. A number of additions and changes were made to the apparatus, and twenty-three runs conducted. The year's work was largely concerned with methods for regulating the gas pump to give a reasonably constant pressure in the carbonizer, and with improvement of the gas-scrubbing system to insure complete removal of the tar from the gas. Many attempts were also made to prevent the choking of the gas outlet pipes with pitch and dust, as this choking made it hard to insure continuous operation for more than ten to twelve hours. During these changes,

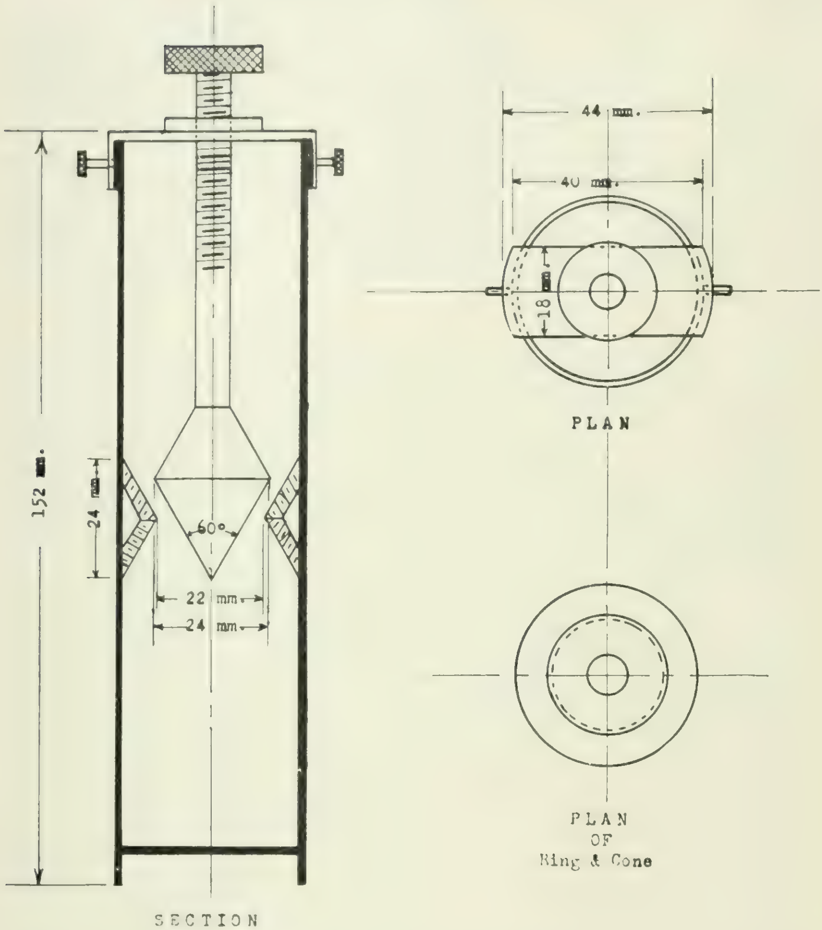

Figure 6.—Centrifuge Cup for Separating Float and Sink in Heavy Solution Work.

the carbonizer proper was jacketed with pipe lagging to reduce heat losses, the gas-scrubbing system was enlarged, a water spray introduced, and a large dust catcher was added at the gas outlet. This latter appeared to have solved the choking difficulty, but no long run was made subsequently. Further work was concerned with the drying of the coal. In the earlier runs, the carbonizer was fed with dry coal, but it was recognized that for commercial operation the preliminary drying of the coal involved a large additional cost. A gas-heated drier was therefore constructed as an integral part of the carbonizer. In a commercial unit this would be heated with the waste heat from the carbonizer proper. Tests showed that this drier worked satisfactorily, and in fact the operation of the whole system became even better than before. In the later work, test runs of six to eight hours were made under varying conditions to ascertain the yields and analyses of the different products and

by-products. Mr. A. E. Cameron, of the Mining Engineering Department, helped during June with this work, and particularly with the construction of the drier. Mr. N. H. Atkinson made all runs from October to December. Table VII. indicates briefly the type of results obtained.

TABLE VII.

Run No.	15	14	7	9	16	10	19
Date 1922	Oct. 12	Oct. 10	June 16	June 27	Oct. 17	July 11	Dec. 1
Total coal carbonized lbs.	53	60	61	250	46	99	53
Rate of carbonization:							
Coal charged per hr., lbs.	11.7	11.6	12.0	13.2	9.4	10.2	9.7
Char discharged per hr. lbs.	7.0	6.9	6.7	7.5	5.3	5.5	5.5
Yield of carbonized coal, or char:							
per 100 lbs. coal as charged, lbs.	59.3	59.7	55.4	56.8	57.0	53.7	56.5
per 100 lbs. dry coal, lbs.	72.6	71.3	68.7	70.5	68.9	66.7	64.8
Yield of tar (moist):							
per 100 lbs. coal as charged, lbs.	2.5	1.6	3.6	3.5	2.6	2.2	0.9
per 100 lbs. dry coal, lbs.	3.1	1.9	4.4	4.3	3.1	2.7	1.0
per 100 lbs. char, lbs.	4.3	2.7	5.2	6.2	4.5	4.1	1.5
Yield of gas:							
per 100 lbs. coal as charged c.f.	146	152	204	163	198	266	352
per 100 lbs. dry coal, c.f.	178	182	252	202	240	330	404
per 100 lbs. char, c.f.	246	255	366	287	347	496	622
Analysis of coal as charged:							
Moisture %	18.3	16.3	19.4	19.4	17.3	19.5	12.9
Ash %	....	....	7.9	7.5	....	6.8	....
Volatile matter %	36.2	33.9	31.7	28.2	32.2	....	35.8
Fixed carbon %	....	....	41.0	44.9	....	....	....
Calorific value B.t.u. per lb.	....	....	....	9,190	....	9,270	....
Analysis of char:							
Ash %	....	....	11.8	12.6	....	13.3	....
Volatile matter %	16.8	15.2	15.2	13.8	13.8	....	8.2
Fixed carbon %	....	....	73.0	73.6	....	....	....
Calorific value B.t.u. per lb.	....	....	....	12,420	....	12,740	....
Moisture in crude tar %	21.4	21.4	....	....	23.6	....	13.6

NOTE:—The runs are arranged in order of increasing degree of carbonization. Tar yields are given over the whole period of a test; other yields and analyses are given for a steady period during the middle of a run, thus excluding the starting and stopping. Gas volumes are calculated to gas measured moist at 60°F. and 30-in. of mercury pressure.

BRIQUETTING

The briquetting equipment ordered in February was not delivered at the University until October, and was not ready for operation until December. It was therefore only possible to make a few preliminary tests during 1922. The press, made by Robert Middleton & Co., Leeds, England, is a small capacity, strongly-built machine, designed for experimental work rather than for commercial output. It is of a horizontal double-plunger type, and is rated to exert a pressure of two tons per square inch, or seven tons in all, upon the briquette. This pressure is exerted through, and controlled by a spring. The briquettes are oval, 2½-in. long, 1¾-in. across, but of varying thickness, usually 1 to 1½-in. The press is driven at a speed to make 25 briquettes a minute, and thus has an output of 4½ pounds per minute when making 3-ounce briquettes. Simple adjustments make it possible to regulate the feed, and therefore the size of the briquette; also the pressure exterted, and, to a slight extent, the duration of the pressure. Accessory equipment includes a small, steam-jacketted batch mixer, and a larger mixer, or fluxer, which is also steam-heated, and from which the mixture is discharged by gravity into the feed hopper of the press. Steam can be blown into the mixture in either the mixer or the fluxer at will. The foundation for the press, which was required to have a total height of about eight feet, was designed by Professor I. F. Morrison of the Civil Engineering Department, and constructed by the University Works Department. The latter department also erected the accessory machines, all the necessary hangers, shafting, pulleys, etc., and made the steam connections. N. H. Atkinson supervised all construction work. Only eight batches of briquettes were made during 1922, but these at least served to indicate that the equipment is well suited to the proposed investigations.

BOILER TRIALS

by Charles A. Robb

Professor of Mechanical Engineering

University of Alberta

Report of boiler trials conducted at Plant No. 2 of the University of Alberta at Edmonton.

Introduction

The boiler trials have been conducted at the request of the Scientific and Industrial Research Council of Alberta for the purpose of establishing the relative values of the different Alberta coals in the generation of steam.

It is to be noted that the furnaces on which the trials were carried out are specially constructed to burn the local coals.

Preliminary runs were made to permit the staff to become familiar with the characteristics of the coal to be tested. The trials in all cases were of eight hours duration.

The water fed to the boiler was measured by means of a Cochrane V-notch meter and the coal was weighed on a Fairbanks platform scale.

The alternate method (A.S.M.E.) of conducting boiler trials was used throughout.

The order of treatment of the coals is based on Bulletin No. 25 of the Mines Branch, Ottawa, "Analyses of Canadian Fuels."

Descriptions of Boilers

The boilers are Babcock and Wilcox water tube: heating surface, 2,197 square feet; builder's rating, 220 h.p. The hand-fired unit has a grate area of 44 square feet, the furnace being a Dutch oven type with fixed grates. The chain grate stoker, which is special, has a grate area of 60 square feet and close links.

Acknowledgments

All the coals were obtained through the Research Council.

The analyses and determinations of the calorific value for Test No. 23 is the work of Mr. J. A. Kelso, Provincial Analyst, and for Tests Nos. 24 and 25, the work of Mr. R. T. Hollies of the Industrial Research Department.

Mr. H. A. McMillan, engineer in charge of Plant No. 2, maintained the boilers in proper working condition, and assisted in carrying out the trials.

Messrs. R. T. Hollies, J. W. Lewis and F. C. Smith assisted.

TABLE VIII.—SUMMARY OF RESULTS OF BOILER TRIALS

1. Area	Drumheller	Big Valley, etc.	
2. Kind of coal	Monarch	Big Valley	
3. Number of coal	(14)	(15)	(16)
4. Grade of coal	Domestic	Domestic	Domestic
5. Test number	B-23	B-24	B-25
6. Date of test, 1922	24 Feb.	21 Nov.	22 Nov.
7. Method of firing	Hand fired	Stoker fired	Hand fired
8. Calorific value, fuel as fired, gross, per lb., B.T.U.	9,830	8,400	8,660
9. Total coal fired, wet, lbs.	10,600	14,600	14,010
10. Total coal fired, dry, lbs.	9,063	11,636	10,998
11. Average coal consumption per hour, lbs.	1,325	1,825	1,751
12. Ash, clinker and refuse, less moisture, lbs.	959	1,973	2,072
13. Total combustible, lbs.	8,104	9,663	8,926
AVERAGE PRESSURES AND TEMPERATURES:			
14. Steam pressure gauge, lbs. per sq. in.	146.7	146.2	144.3
15. Temperature of feed water, F.	167.4	137.2	149.4
16. Barometer, ins. Mercury	27.93	27.55	27.85
17. Draft over fire, ins. Water	0.40	0.44	0.56
18. Carbon dioxide, %	8.4	11.5	11.3
19. Temperature of flue gases, F.	491	390	504
WATER:			
20. Total water evaporated at feed temperature, lbs.	52,626	76,436	61,383
21. Water evaporated per hour, lbs.	6,578	9,555	7,673
22. Total equivalent evaporation from and at 212 F., lbs.	56,678	84,691	67,214
23. Hourly equivalent evaporation from and at 212° F., lbs.	7,085	10,586	8,402

ECONOMIC RESULTS:			
24. Water evaporation per lb. coal, actual conditions ....lbs.	4.96	5.24	4.38
25. Equivalent evaporation per lb. coal from and at 212°F. ....lbs.	5.35	5.80	4.79
26. Equivalent evaporation per lb. coal (dry) from and at 212°F....lbs.	6.25	7.28	6.11
27. Equivalent evaporation per lb. coal (combustible) from and at 212 F. ....lbs.	6.99	8.76	7.53
28. Factor of evaporation	1.077	1.108	1.095
29. Dryness of steam, assumed ....%	98	98	98
EFFICIENCY:			
30. Efficiency of boiler and furnace ....%	52.6	66.7	53.4
31. H.P. developed per hour	205	307	244
32. Percentage of builder's rating	93	140	111
PROXIMATE ANALYSIS:			
33. Fixed carbon ....%	43.3	38.5	40.2
34. Volatile matter ....%	34.4	28.9	28.9
35. Ash ....%	7.8	12.3	9.4
36. Moisture ....%	14.5	20.3	21.5
ANALYSIS OF ASH:			
37. Combustible ....%	32.6	13.5	19.3
38. Ash ....%	67.4	86.5	80.7

GEOLOGICAL INVESTIGATIONS DURING 1922

BY JOHN A. ALLAN

During the year 1922 the writer directed two field survey parties, and visited several different localities within the province to investigate mineral possibilities. Before the field season began, considerable time was spent on the report on the "Geology of the Drumheller Coal Basin," which was ready for distribution in May as the Third Annual Report on the Mineral Resources of Alberta, 1921. The geological survey of the Drumheller coal basin was the beginning of an extended program of field work on various coal basins in Alberta.

Two districts were examined geologically during the summer of 1922, and the results of these investigations are given in some detail as the Fourth Annual Report on the Mineral Resources of Alberta, 1922, so only a brief summary will be given here.

SAUNDERS CREEK AND NORDEGG COAL BASINS

The area surveyed covers about 650 square miles, and extends along the Canadian National Railway (Brazeau branch) from mile 125 west to Nordegg (mile 173), and from Saskatchewan river north to the Nordegg and Blackstone rivers at the north boundary of township 43. Nearly four months were spent in the field. The regular party consisted of four men, with R. L. Rutherford in charge and J. O. G. Sanderson as assistant geologist. The writer also spent as much time as possible with this party. The results of the investigation are contained in the Fourth Annual Report on the Mineral Resources of Alberta, Part I., entitled "Saunders Creek and Nordegg Coal Basins," prepared by the writer and R. L. Rutherford. The report is accompanied by a geological map on the scale of two miles to the inch.

In this area there are two distinct coal basins. The coal measures in the Saunders creek basin are of upper Cretaceous age, and correspond to the Belly River coal formations in central and southern Alberta. The Nordegg coal measures are in the Kootenay formation, of lower Cretaceous age.

The structure and distribution of the coal measures in the two basins, and the associated formations, have been mapped as accurately as field data would warrant. The basins are separated by an outlier of the Rocky mountains, known as the Brazeau range, which consists largely of Palaeozoic rocks.

The structure in the Saunders Creek basin is simple, and consists of a broad syncline to the east, a narrower anticline, and a slightly overturned, asymmetrical, syncline to the west. The coal seams are contained in a series of beds about 170 feet in thickness. There are at least four, and possibly five coal seams in the measures,

but only two have been mined at the present time. There are four mines in operation on these younger measures, namely, Bighorn and Saunders Creek, Saunders Alberta, and Alexo, located on the west limb of the syncline, and Harlech mine on the west limb of the Stolberg anticline. Seam No. 2, numbered from the bottom of the measures, is being worked in all these mines, and No. 4 is being opened up in Harlech mine. The coal appears to be somewhat cleaner towards the west, and especially towards the north-west, but the seams are more faulted and disturbed towards the west. The beds to the west have been subjected to greater deformation when the Brazeau range was being uplifted. Coal seams outcropping near the mouth of Colt creek and the Nordegg show a much more blocky type of coal than along the railway.

In the Nordegg coal basin the coal seams occur near the bottom of the Kootenay formation. There are at least five coal seams in these measures, but only seams No. 2 and No. 3 are being mined by the Brazeau Collieries at Nordegg. This company is the only one operating in this basin. All strata have been affected by forces prevalent during the mountain-building period, so that the coal is intensely crushed, and is extracted in small lenticular fragments. A third seam of coal in these measures is thick enough to work at a profit, but the ash content is high where the seam has been prospected.

A thin, but badly crushed, series of Kootenay beds were discovered on the Saskatchewan at the east end of the gap. At least two coal seams occur in this section, dipping nearly vertically, but the coal is intensely crushed by the overthrust Palaeozoic rocks in Brazeau range, which rise two thousand feet.

The results of this field survey have shown that both the Saunders and Nordegg coal basins extend south of the North Saskatchewan river, but the continuation of these coal basins has not yet been prospected as the district is not readily accessible, the railway following the north side of the valley.

Lake Athabaska Iron Ores

An investigation was carried out in a district on the north shore of lake Athabaska, where a large deposit of commercial iron ore was reported to occur and on which five mineral claims had been staked by E. A. and N. C. Butterfield. This area is in the vicinity of Fishhook and Moose bays on the north shore of lake Athabaska, 56 miles east of the Alberta-Saskatchewan boundary, 112 miles east of Chipewyan and 350 miles from Waterways, the closest railway terminus. The reported occurrence of a commercial deposit of iron ore in this part of Canada, and the fact that any minerals or other resources on lake Athabaska would have to be brought out to market through Alberta, were the principal reasons for the authorization of a field survey of this district in 1922.

The report on this investigation, by Alan E. Cameron and the writer, is called "An Occurrence of Iron Ore on Lake Athabaska," and forms Part II. of the Fourth Annual Report on the Mineral Resources of Alberta, 1922.

The most favorable consideration was given to the problem, but the writers have come to the conclusion that field investigations, analyses of samples, and a microscopic study of the rocks, show that "there is no commercial deposit of iron ore exposed around Fishhook bay; and, furthermore, that the surface exposures do not indicate that enrichment can be expected at depth which would produce an economic deposit of iron."

Chapter II. in this report includes a discussion of the commercial possibilities of producing iron ores from lake Athabaska district, "assuming that large deposits of high grade ore are discovered in the future." The conclusion arrived at is that the cost of transportation of ore, fuel and other materials, and the decidedly limited market of the products, "prohibit for the present time the commercial development of any iron ore deposits which might be found about lake Athabaska."

This report is accompanied by a geological map of lake Athabaska district, a sketch map of Fishhook bay, and several photographs and photomicrographs which show the type of country and the character of the iron-bearing rocks.

PONOKA GAS WELL

In May, the writer made an examination of the gas well at Ponoka, at the request of Hon. Alex. Ross, Minister of Public Works. A report was requested on the supply of gas available, for use in certain departments in the Provincial Hospital for the Insane, and on the advisability of drilling another well. After investigating all available data on the depth of the well and the gas supply encountered when drilling, the recommendations made included the following: (1) that it is not advisable to drill another well, as an adequate gas supply for the whole institution could not be expected; (2) that since the gas pressure on a Bourdon gauge on the top of the well casing was 490 lbs. when the examination was made, it was advisable to have a capacity test made of the gas flow over a period of several days to determine the available daily flow of gas.

This test was carried out later by C. A. Robb over a period of about two weeks, and his report shows that the gas well has an assured daily capacity of 60,000 cubic feet for some years.

SOILS SURVEY

Four days in September were spent in the field in company with Dr. F. A. Wyatt, who was conducting a soils survey in the southeastern part of the province. The object of this investigation was to determine the distribution of the glacial deposits and the relation of these deposits to the soil types. In this short period the district examined included from Medicine Hat, north twenty miles, west to Champion, and south to Nobleford. The approximate dis-

tribution of the glacial moraines was noted, and details of this investigation are included in a report made to the Soils Department.

The necessity is apparent of more extended and detailed surveys of the glacial deposits throughout Alberta in order to interpret the distribution of certain types of soil.

Other Investigations

Preliminary investigations were made on the structure east and south of Viking, where there are petroleum possibilities, and also on the Sweet Grass arch in the vicinity of Coutts, Alberta, where drilling has been started during the year to prove petroleum indications. The recently developed Sunburst-Kevin oil field in Montana was also visited. Drilling began on this structure about a year ago, and there are today over 30 producing wells, and over 100 drills at work. There are producing wells within ten miles of the southern boundary of Alberta, so that prospects are hopeful for the discovery of petroleum in commercial quantities on adjoining Canadian lands.

During the year, about seventy specimens were examined in the laboratory, of which twenty-two were clays. Only shrinkage and low-temperature burning tests can be made with the ceramic equipment now on hand.

THE BITUMINOUS SANDS OF NORTHERN ALBERTA

THEIR SEPARATION AND THEIR UTILIZATION IN ROAD CONSTRUCTION

BY K. A. CLARK

INTRODUCTION

Investigation has been continued throughout the year 1922 of ways and means of converting the Northern Alberta bituminous sand deposits into an economic asset of the province. The Second Annual Report contained a general discussion of the factors involved in dealing with the problem of commercially developing the bituminous sands. This report will present a discussion of the experimental work which has so far been carried out in the attempt to find a solution for the problem.

The problem of the commercial development of the bituminous sand deposits appears to be two-fold in nature: it involves the invention of a suitable scheme for separating from each other the bituminous and mineral constituents of the bituminous sand; and it also involves the development of a market for the separated bitumen of sufficient magnitude to justify commercial operations. It has been frequently suggested that the crude material could be excavated and shipped to cities and towns in the province for direct use in the construction of bituminous pavements. It is apparent, however, from the experience of the past season in the construction in Edmonton of bituminous sidewalks, as noted later, that building pavements with crude bituminous sand is both complicated and costly. The Edmonton sidewalk experiment supports the contention that the primary step in any scheme of commercial development must be in the separation of the bitumen constituent of the bituminous sands from the sand which constitutes the bulk of the deposit. In keeping with this contention, experimental work has been under way during the past two years for the purpose of devising a process for such separation. Good progress has been made. The separation, however, is only a primary step towards the solution of the bituminous sand problem. There must be a market for the bitumen when separated. The opinion was stated in the Second Annual Report that it would not be commercially feasible, for some years to come, to manufacture from bituminous sands substitutes for such refined petroleum products as motor spirits and lubricants. Nothing has come to light since to modify that opinion. The natural market for the bituminous sand bitumen is the same as that for other asphalts, namely, the market created by pavement and road construction. Although evidence is against the practic-

ability of crude bituminous sand for building pavements, there seems to be reason to hope that the case will be otherwise for the separated bitumen. The possibility of developing a prairie type of stabilized earth road by the use of a cheaply separated bituminous sand asphalt is particularly interesting.

Development of Method of Separation

A scheme of separation of the bitumen content of the bituminous sands often advocated by development promoters is that of retorting, or of destructive distillation. This method of procedure was the subject of a considerable part of the discussion of the bituminous sands in the Second Annual Report. No further comments will now be offered. Instead, I wish to discuss the plan of separation which is being followed in the laboratory of the Industrial Research Department.

The scheme of separation of the bituminous sand bitumen from its associated sand and silt which is being developed in the Industrial Research laboratory has grown out of an idea that occurred to me some years ago while working for the Mines Branch, Department of Mines, Ottawa, on road materials surveys on the prairies. I was particularly impressed by two observations which I made: the great lack of stone and gravel deposits in the prairie provinces as compared with the eastern provinces; and the surprising stability, during dry weather, of many of the prairie earth roads. Construction of the ordinary types of road surfaces, which depend on the use of stony material, seemed out of the question. On the other hand the prairie earth road was obviously inadequate. Many of the earth roads were good under ideal weather conditions, but wet periods made them, in many cases, impassable. The question naturally arose of whether it was possible to stabilize the prairie earth road by treatment with small quantities of some available material, and thereby to fix them in such a way that their good qualities would persist through wet weather. The idea of the use of bituminous emulsions came to my mind. I knew of the Alberta deposits of bituminous sand. Why not emulsify the asphaltic bitumen which they contained?

It was not until the winter of 1919-20 that I secured a sample of bituminous sand with which to experiment. The attempt was then made to emulsify its bitumen content by means of a soap solution. The result of the experiment was not what was expected, but was very interesting. When a sample of bituminous sand was shaken with a solution (preferably a hot solution) containing one per cent. or so by weight of soap, emulsification did not result, but a separation of sand and bitumen took place. Clean sand and small particles of bitumen could be seen through the glass vessel in which the experiment was performed. The bitumen did not float: consequently, though the two constituents were separated in the sense that they were no longer adhering the one to the other, they were nevertheless mixed together. The sight of the clean sand and separated bitumen gave one the impression that there was little left of the problem of separating the bituminous sand into its constituents. Yet all atttempts to get the bitumen into one vessel and the

sand into another became involved in difficulty. If a sieve was placed in the solution to collect the bitumen and allow the sand to pass, the sieve promptly became hopelessly tarred. All arrangements to utilize a sieve ran foul of this trouble. Attempts to wash the sand and bitumen apart were unsatisfactory. The expedient of introducing a light oil, such as kerosene, into the bituminous sand, in order to lower the specific gravity below that of water, was tried. It was expected that in this way the bitumen could be induced to float. However, the separated bitumen seemed always to enmesh enough sand to keep it weighted down unless an excessive quantity of kerosene was added. The problem of separation was at this stage when I joined the staff of the Scientific and Industrial Research Council of Alberta at the University of Alberta.

The investigation pursued in the Industrial Research Department has been a continuation of the line of work commenced at Ottawa. Solutions of substances other than soap have been tried. Among these may be mentioned sodium hydroxide, sodium carbonate and silicate of soda. All of these solutions accomplish the same result of causing the bitumen content of the bituminous sand to become comparatively non-adherent to the sand. The problem resolved itself into that of effecting the removal of the bitumen from its associated mineral matter after these two constituents of the bituminous sand had been caused to separate from one another. Many schemes have been tried and discarded. The original idea of emulsification was tried. It was found that when a small portion of kerosene was added to the bituminous sand, and the mixture was agitated in a hot solution containing both soap and silicate of soda, the bitumen dispersed. A layer of emulsified bitumen rose to the top, and the sand settled to the bottom after a period of settling. However, it was difficult to collect the emulsion without again dispersing it in the solution. In any case there was a great deal of water present with the emulsion. A Sharples centrifuge was secured to facilitate the separation of the bitumen from its associated water. This scheme failed because of the presence in the emulsion of very finely divided mineral matter which refused to settle out by gravity. This mineral matter deposited in the centrifuge and choked it. Another set of experiments followed up the observation that when the bituminous sand, after treatmtent with a soap or silicate of soda solution, was placed on the surface of a body of hot water the bitumen tended to film out and remain on the surface while the sand broke through and sank. However, a good deal of sand also floated, and a good deal of bitumen sank. A sandy bitumen concentrate and tarry sand tailings were the constant result. A scheme of aeration of the separated bitumen by the aid of soap froth was devised for the purpose of making the bitumen float; but it was difficult to carry out the scheme except on small quantities of material, and sand tailings free from bitumen were seldom obtained. Attempts were made to wash the sand away from the bitumen. A trial run with cold, separated, bituminous sand on a Wilfley table gave some encouragement, but no satisfactory method of procedure was found.

A scheme which was finally found for removing the separated bitumen from the sand gives good promise of being commercially

feasible. The bitumen is floated on hot water. No addition of kerosene or other oil is made. A bitumen concentrate is obtained which contains less than 15% (and occasionally as low as 5%) of very finely divided mineral matter, and from 15% to 20% of water. The sand tailings retain about 1%, only, of bitumen. Runs of 100 pounds of bituminous sand have been handled in the small trial apparatus so far employed. A small plant, provided with appropriate mechanical contrivances for continuous operation, is now in process of construction. It will handle about one-half ton of bituminous sand per hour. One hundred tons of bituminous sand are on hand for treatment in the trial plant. The attempt to separate this quantity of material should determine fairly definitely whether the present scheme of treatment is a possible commercial process. The cost of production of bitumen concentrate will also be determinable from data collected during the experiment. Details of the methods and results will be published in a later report.

Fyleman's Process

Study of the problem of the separation of the bituminous sands has not been confined to the Industrial Research Laboratory, nor even to Canada or to America. Our bituminous sand deposits are well known in England, and English technologists have given them their consideration. An English chemist, Ernest Fyleman, has recently published a very interesting paper* on his work on separating the bituminous sands. It appears that Fyleman has been following up a very similar idea to that which underlies the work that has been proceeding in our own laboratory. He has found that treatment of bituminous sands (the Alberta bituminous sands are particularly mentioned) with dilute solutions of alkali salts or hydroxides, of soap or other froth-forming substances, or of dilute acids, result in a drawing away or separation of the bitumen from the sand. A patent† for this process has been granted to him. The problem of removing the bitumen from the sand after these constituents have been caused to separate from one another is lightly passed over by Fyleman. He says, for instance: "The aqueous liquid can be used indefinitely to repeat the process with fresh quantities of tar sand, and the sand particles, which are very fine, can be flushed away through a coarse sieve, or separated by any of the usual hydraulic separating devices, leaving practically pure bitumen together with about 10 per cent. of water, which it loses on heating." Fyleman's patent specification also mentions the expedient of introducing kerosene into the bituminous sand in order to cause the separated bitumen to float.

Theory of the Separation Phemomenon

Fyleman offers a theoretical explanation of the phenomenon on which his patent is based: namely, the drawing away of the bitumen from the sand of a bituminous sand when the latter is

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*Fyleman, Ernest: The separation of adherent oil or bitumen from rock; J.Soc.Chem.Ind., XLI., 2, (Jan. 31, 1922) pp. 14T-16T.

†Br. Pat. 163519, 1920; Can. Pat. 203676, 1920.

treated with a suitable solution. The explanation is based on the surface energy relationships laid down by Reinders* as governing the distribution of an insoluble solid between two immiscible liquids. The argument is that, in a system consisting of bituminous sand and an aqueous solution, the sand will not break its association with the bitumen unless conditions are such that the surface energy developed by the sum of all the interfaces between bitumen and sand is greater than would be the case if the sand surfaces were in contact with solution. When this condition is fulfilled, then, in accordance with the principle that a system always tends to change in such a way as to reduce its free energy content, the sand-bitumen interfaces will break down, and sand-solution interfaces will be established. Solutions of substances which are found to bring about the separation of the bituminous sands are considered to establish the surface energy relationship demanded by the theory.

This explanation of the separation of bitumen from sand when bituminous sands are treated with proper solutions is a simple one: but it leaves out of consideration several features which I have observed to be always associated with the separation phenomenon. Fyleman's theory requires as the necessary and sufficient condition for separation, that the bituminous sand be in contact with an aqueous solution which will cause the development of less surface energy at a sand-solution interface than exists at the sand-bitumen interface. When this condition is made to exist, the contact between sand and bitumen should disappear. No modification of the bitumen phase is called for. Yet it seems true that a modified bitumen phase is always present when conditions are right for separation. Further, samples of bituminous sand in its natural state can be found in which the bituminous phase is sufficiently modified to permit separation to take place in pure water. The modification of the bitumen to which I refer is the presence in the bitumen of water, probably in the emulsified form. If the bitumen of a sample of bituminous sand is sufficiently "wet," it will not adhere to the sand surfaces. The primary function of the solution which causes the separation phenomenon is, to my mind, to create a condition under which water enters or becomes emulsified in the bitumen. When the water content of the bitumen has become sufficiently high, the separation of sand from bitumen, if given a chance, will take place.

My contention, that the separation phenomenon is dependent upon a sufficient water content in the bitumen of the bituminous sand, is based on a number of observations. Examination of samples of fresh bituminous sand always shows quite a high content of water. Reckoned on the basis of water present in the "wet" bitumen constituent, the water content has varied from 4% to 17% in the samples which I have examined. The water content of a bituminous sand sample drops rapidly when exposed to the air. I have followed the decrease from 7.5% to 2.5% of water during five days in the case of one sample. After several weeks, the water content had dropped to 0.5%. A sample of bituminous sand, when freshly removed from an exposure at the deposit, often appears

*Kolloid Zeitschrift, 1913, p. 235.

quite brown. This is particularly true if the water content is high. Samples containing less water are increasingly dark in appearance. An uninitiated observer naturally arranges samples of bituminous sand in the order of their richness in bitumen by the blackness of their color. It is quite a surprise to him when he discovers that the bitumen contents of all his samples are about the same, and that it is the water content that is variable. If the surface of a fragment of fresh, brownish, bituminous sand is rubbed lightly with the finger, the surface appears to turn white or whitish. Close examination shows that perfectly clean quartz sand surfaces are exposed. The gentle brushing breaks the bitumen envelopes surrounding the sand grains, and the bitumen then tends to draw away from the sand surface, bringing it plainly to view. This result cannot be obtained with a black sample of bituminous sand. The bitumen of low water content does not draw away from the sand surface to which it is adhering. A supply of freshly mined bitumen is easily amenable to the process of separation. A very short period of treatment with a soap or other suitable solution causes the segregation of the bitumen and sand. I have worked with fresh samples which required no treatment with solution at all; the bitumen and sand drew apart when the sample was stirred up in pure hot water. As the bituminous sand becomes old and dry, it is increasingly hard to treat. The explanation which appeals to me is, that the lower the water content of the bituminous sand to be treated, the longer the time required to bring up the water content of the bitumen to a sufficiently high value for separation. Finally, bitumen concentrates obtained by the separation process always have a high water content, ranging as high as 25 per cent. Surface energy relationships are undoubtedly responsible for the separation phenomenon. But it is my conviction that the introduction of water as an internal phase into the bitumen is an essential step in the mechanism of separation of the bituminous sands by means of aqueous solutions.

USE OF CRUDE BITUMINOUS SANDS IN PAVEMENT CONSTRUCTION

The construction of asphalt pavements would appear, on first sight, to be a most logical and straightforward procedure for putting the Alberta bituminous sands to economic use. This material is a natural mixture of sand and asphalt—the two principal constituents of sheet asphalt pavements. Successful pavements have been built in many parts of the world with such native bituminous materials. Alberta cities and towns are covering their streets with sheet asphalt compounded by the use of asphalt imported from afar and at a high price, in spite of the fact that the Alberta bituminous sand deposits exist and offer a home supply of asphalt naturally mixed with sand. It might appear that the blunder was being committed of importing pavements while a deposit of ready-made paving material existed at hand. This aspect of the situation has caught the attention of the layman, with the result that the use of the bituminous sand for paving purposes has long been advocated. The engineer, more conversant with the various factors

involved in the efficacy and cost of construction projects, has not been so impressed. So long as transportation facilities to the bituminous sand deposits were lacking, no convincing test of the practical suitability of the bituminous sands for pavements was possible. During the past year, however, facilities for mining and transporting the bituminous sands became available, and two carloads of material were shipped to Edmonton and used in construction work. As a result of the trial, the question of whether Alberta communities can build a pavement more economically and as efficiently through the use of bituminous sand as in the customary way with imported asphalt can now be given a fairly definite answer.

Bituminous Sand Pavements

The construction of pavements with bituminous sand—even with the Alberta bituminous sand—is no innovation. Rock asphalt pavements made from bituminous limestones and sandstones have been well known in European cities for seventy-five years. Streets and roads have been successfully paved in California by the use of bituminous sands very similar in character to those occurring in Alberta. The Alberta bituminous sands themselves have been experimented with at various times in the construction of stretches of pavement. The site of these experimental trials has very naturally been in Edmonton. Two small squares of sidewalk surface were put down in 1912 by Mr. Russell, president of the Vulcan Asphalt Co., of Winnipeg. Each consists of about sixteen square feet of surface: one near the south-west corner, the other near the north-west corner of Jasper Avenue and 101st Street. At a somewhat later date another square of sidewalk was laid near the corner of Jasper and Namayo by the Nakamun Asphalt & Oil Company. These pieces of sidewalk are still in place, and form interesting evidence of the succession of attempts that have been made to further the development of the bituminous sand deposits. Quite a pretentions piece of experimental construction was undertaken in 1915 by the Federal Government. The undertaking was engineered by S. C. Ells, a member of the staff of the Mines Branch, Department of Mines, at Ottawa, who, since 1913, has been closely associated with the study of the Alberta bituminous sand deposits. About twenty tons of bituminous sand were mined near Fort McMurray and transported by team to Athabaska Landing, and from there by rail to Edmonton. The bituminous sand was worked up into pavement aggregate and laid on a concrete foundation prepared by the City of Edmonton along a stretch of 618 yards on the Fort Trail, commencing at 82nd Street and 118th Avenue. The stretch is divided into approximately equal lengths of sheet asphalt, asphaltic concrete, and bithulithic pavement. The pavement has borne fairly heavy traffic since it was laid, and is still in good condition. Finally, during the construction season of 1922, the City of Edmonton secured two carloads of bituminous sand, and with this material laid sheet asphalt surfaces on sidewalks on 102nd Avenue between 100th Street and 99th Street and between 97th Street and 96th Street; on 104th Avenue between 97th Street and 96th Street, and on 96th Street just north and south

of the C. N. R. crossing. The trials in Edmonton have indicated that it is possible to make serviceable pavements by the use of the Alberta bituminous sand. The sidewalk surface construction undertaken by the City of Edmonton in 1922, however, is the only work so far accomplished which throws light on the question of whether construction of pavements by the use of Alberta bituminous sand is practicable and economical.

A sheet asphalt pavement mixture consists of a mixture of sand and asphalt. But any mixture of sand and asphalt will not do. Long experience in the designing of pavements to meet the requirements of traffic has revealed the fact that the sort of sand and the sort of asphalt which are mixed together to make an asphalt pavement must be quite carefully watched and controlled. The sand must be of the right coarseness and grading: the asphalt must be of the right consistency or hardness. Moreover, the sand and the asphalt must be mixed together in the right proportions. Experience has led to the formulation of specifications which define by fairly narrow limits the character of the sand, the nature of the asphalt, and the proportions of mixing, for the building of an asphalt pavement. If these specifications are followed, a good pavement is the result; if they are disregarded the result is very likely to be a failure. A pavement built by the use of bituminous sands is not free from the limitations set by experience in artificially mixing asphalt and sand. It is a comparatively simple matter to procure sand of the proper grading, to buy asphalt of a suitable nature, and to mix the two together in the right proportions. It is a much more complicated matter to commence with bituminous sand, and to then doctor it up by additions and modifications till a final product is obtained which has a composition that corresponds with sheet asphalt specifications. The Alberta bituminous sand, for instance, contains a sand that is much too fine, and an asphalt that is much too soft. Further, the asphalt is present in too large a proportion. Very material modification of the nature of the bituminous sand must be effected if a suitable pavement is to result from its use. Extra sand must be added to bring down the content of asphalt to the right value. Moreover, this extra sand must be so chosen as to correct as far as possible the fault which the natural sand content of the bituminous sand has of being too fine. There will still remain the defect that the asphalt contained in the bituminous sand mixture is too soft. This defect must be overcome by a special heat treatment of the mixture whereby some of the asphalt will be volatilized and the harder portions only of the asphalt retained. Complicated procedures are more expensive to carry out, and harder to accomplish successfully, than are simpler ones. For this reason the use of bituminous sand is at a disadvantage in comparison with the simple procedure of mixing together a suitable sand and asphalt.

Bituminous Sand Sheet Asphalt Sidewalks

A full account of the details of the construction of the bituminous sand sheet asphalt sidewalks has been prepared by Mr.

C. C. Sutherland, of the City Engineer's staff, City of Edmonton, and will be published in The Canadian Engineer. Only a brief outline of the work will be given in this report.

A shipment of about twenty tons of bituminous sand was delivered to the City of Edmonton paving plant in August last. This material was bought from the McMurray Asphaltum & Oils, Ltd., at Waterways, Alta. Representative samples of the shipment were taken during the process of unloading, and submitted to the Industrial Research Laboratories for examination. Tests showed that the material contained on the average 20% of bitumen. The sand constituent was very fine, consisting of about 15% of silt passing a 200-mesh sieve, and approximately equal parts of sand particles retained on the 100 and 200-mesh sieves. The bitumen contained in the bituminous sand was very soft in comparison with asphalt used for paving work. Making use of the results of the tests on the samples of the shipment, and of mechanical analyses on stocks of sand at the paving plant, a combination of bituminous sand and sand used for concrete was deduced which gave a mixture approaching fairly well a standard sheet asphalt mixture. Some portland cement was also added to the combination to serve as filler. A small, heated, rotary mixer, used for mixing the material for the bituminous and pavement laid by the Dominion Department of Mines in 1915, was secured, and used again for preparing the aggregates for the bituminous sand sidewalks. Batches of about 1,000 pounds were handled at a time, and were mixed and heated during periods ranging from 30 to 60 minutes. This operation caused the evaporation of about 10% of the bitumen contained in the mixtures, and caused a hardening of the bitumen. After the mixing and heating, the bituminous sand mixtures were hauled to the sidewalks, and spread and rolled in the way sheet asphalt is laid. Two stretches of bituminous sand sidewalk were built, one on the north side of 102nd Avenue between 99th and 100th Streets, and the other on the north side of the same avenue 96th and 97th Streets. Both sidewalk surfaces were laid on old, compacted, cinder foundations. The finished sidewalks had a good appearance, and, although a little soft for sheet asphalt, will probably prove quite satisfactory.

A second carload of bituminous sand was sent to the City in September. Examination of this shipment showed an average bitumen content of 17%. The bitumen was still softer than that contained in the first carload; the sand constituent was considerably finer, and contained over 20% of silt. This shipment was made up into sheet asphalt in much the same way as the first. Sidewalks on fresh cinder foundations were laid on 104th Avenue between 96th and 97th Streets, and on 96th Street immediately north and south of the C. N. R. crossing. These sidewalk surfaces turned out to be much softer than those prepared from the first carload of bituminous sand.

A few remarks by way of explanation of the softness of the surfaces prepared from the second carload of bituminous sand should probably be offered. As already mentioned, the second shipment of material contained a very soft bitumen and very fine sand. These features would naturally tend towards the production of soft

pavement mixtures. This tendency was probably exaggerated by a change that was made in the heating of the batches in the rotary mixer. In order to cut down the time of mixing, the firebox was modified in a way that was calculated to give much more intense heating. It seems probable that the desired result was not secured, and less evaporation and hardening of the bitumen was secured than in the case of batches prepared from the material in the first shipment.

Cost of the Bituminous Sand Sheet Asphalt Sidewalks

The deciding factor of practical suitability of the crude Alberta bituminous sands for pavement construction is the cost of such construction in comparison with the cost of equivalent construction by means of imported asphalt and the procedure ordinarily practised. The nature of the bituminous sand makes its employment for pavement purposes a more troublesome and complicated affair than the established method of building bituminous pavements. But if a real saving in money can be gained by the use of the bituminous sand, the difficulties attending its use can be faced and overcome. If, however, there is little or no saving of money to be made, the case will have to be decided against the practical suitability of crude bituminous sand for pavement work.

A direct comparison of the cost of construction of a sheet asphalt sidewalk surface by the use of bituminous sand with the cost of the same sidewalk constructed by means of imported asphalt presents a difficulty. It is not possible to employ the same equipment for both methods of construction; consequently the question arises whether costs corresponding to the two equipments used form a fair basis of comparison. Bituminous sand could not be handled in the standard asphalt plant, which is designed to heat and mix imported asphalt and clean sand. But imported asphalt and clean sand could be mixed in a plant designed to handle bituminous sands. Table IX. gives the items of cost of building the sheet asphalt sidewalk surfaces from imported asphalt and sand mixed in the bituminous sand mixing plant, as well as the cost of building it from these materials mixed in the standard asphalt plant. Two means of comparison of the cost of bituminous sand construction with the cost of construction with imported asphalt are thus provided.

One of the cost items given in Table IX. should be explained. The high cost item for plant rental, etc., for the small rotary mixer used for handling the bituminous sand aggregates, as compared to the same cost item for the standard asphalt plant, looks unreasonable. It must be remembered, however, that the cost items are reckoned on the basis of cost per square foot of sidewalk surface constructed. The greater relative capacity of the standard plant for output of aggregate accounts for the difference in cost for rental, etc., that must be charged against a square foot of surface.

Some interesting observations can be made from the information contained in Table IX. The third column of figures shows that the cost of the sheet asphalt sidewalk, if built in the customary

way from imported asphalt, is divided between the various items of expense as follows:

Imported Asphalt 16%
Mineral Aggregate 10%
Labor:
  Preparation of subgrade 13%
  Hauling and laying 30
  Labor at plant 23 66%
Plant Overhead 8%

TABLE IX.—COMPARATIVE COST OF SHEET ASPHALT SIDEWALKS PREPARED FROM BITUMINOUS SAND AND FROM IMPORTED ASPHALT

Actual cost of the bituminous sand sheet asphalt sidewalks is itemized in the first column of figures. The second and third columns contain corresponding items of cost for a similar sheet asphalt sidewalk prepared from imported asphalt, and mixed in the small plant used for the bituminous sand and in the standard asphalt mixing plant, respectively. This table of cost data has been compiled by the City Engineer's Department, Edmonton, Alberta.

Items of Cost	Bituminous Sand Sheet Asphalt Sidewalk: Aggregates Mixed in Small Rotary Heater. Cents per sq. ft.		Sheet Asphalt Sidewalk: Aggregates Mixed from Imported Asphalt and Local Sand in Small Rotary Heater. Cents per sq. ft.		Sheet Asphalt Sidewalk: Aggregates Mixed from Imported Asphalt and Local Sand in Standard Asphalt Plant. Cents per sq. ft.	
Preparation of Subgrade		2.00		2.00		2.00
Binder Course, ¾-in. thick:						
Gravel	0.58		0.73		0.73	
Bituminous Sand	1.36		....		....	
Local Sand	0.08		0.12		0.12	
Portland Cement Filler	0.27		....		....	
Imported Asphalt	....		0.98		0.98	
Labor at Plant	1.34		1.34		1.77	
Hauling and Laying	2.39		2.39		2.39	
Plant Rental, Fuel, Oil	1.07		1.07		0.59	
Total	——	7.09	——	6.63	——	6.58
Sheet Asphalt Surface, ¾-in. thick:						
Bituminous Sand	2.72		....		....	
Local Sand	0.21		0.46		0.46	
Portland Cement Filler	0.57		0.27		0.27	
Imported Asphalt	....		1.55		1.55	
Labor at Plant	1.34		1.34		1.77	
Hauling and Laying	2.39		2.39		2.39	
Plant Rental, Fuel, Oil	1.07		1.07		0.59	
Total	——	8.30	——	7.08	——	7.03
Total Cost of Sidewalk		17.39		15.71		15.61

The cost of asphalt forms a comparatively small part of the price of a sheet asphalt sidewalk. No matter how cheaply asphalt could be secured, the cost of a sheet asphalt sidewalk could not be radically reduced.

Bituminous sand will be considered for pavement construction if it provides cheap asphalt. The bituminous sand shipped to Edmonton in 1922 cost $10.50 per ton. The cost was made up of charges, per ton, of $5.00 for mining and loading, $5.00 for freight, and $0.50 for unloading. At the price of $10.50 per ton, the bituminous sand provided asphalt for the sidewalk constructed from it at a cost of 4.08 cents per square foot of sidewalk surface. Imported asphalt* could have been provided for 2.53 cents per square foot. For the bituminous sand to have been on an equal footing with imported asphalt, it should have been secured at a cost of $6.50 per ton, unloaded at the paving plant.

The total costs given in Table IX. for a complete sidewalk show the cost of the sidewalk to be greater when constructed with bituminous sands than when constructed with imported asphalt. It may be argued that it is not fair to compare the cost of bituminous sand construction when using a small and more or less make-shift mixer with the cost of construction with imported asphalt and a large, efficient paving plant. One could maintain that if a large programme of work were undertaken, and the best of equipment were provided, a better cost for bituminous sand construction would result. The saving in cost would arise through a reduction of plant labor and plant overhead charges against a unit quantity of aggregate mixed in the plant. But it is also true that if a large construction programme, using imported asphalt and the standard paving plant, were undertaken, unit plant labor and plant overhead charges would be reduced. These items of cost in Table IX., last column, are the actual costs for 1922, which was a slack season in which only about 8,800 square yards of asphalt repair work was done. It would appear, consequently, that no matter how costs are compared, provided that the method is a fair one, construction by means of bituminous sand will prove to be at least as costly as by the established method using imported asphalt.

It must be clearly borne in mind that sidewalks, and not street pavements, were constructed in Edmonton in 1922. The sidewalks constructed, from the first shipment of bituminous sand, at least, were successful: but it is far from certain that the same material laid as a street pavement would have withstood vehicular traffic. It is very doubtful whether the bituminous sand of the second shipment, with its very soft bitumen content and excessively fine sand constituent, could possibly have been made into a sheet asphalt aggregate that would be stable enough for street traffic. It is true that the Dominion Department of Mines built a street pavement from bituminous sands, that the pavement has successfully withstood fairly heavy traffic for seven years, and that it is still in good condition. But the bituminous sand that went into the pavement consisted of a mixture of several grades of material, some coarse

*In 1922 the City of Edmonton bought asphalt for pavement construction at $42.95 per ton, f.o.b. Edmonton.

and some finer, and so chosen that they would combine to give a sand constituent with a grading approximating that demanded by sheet asphalt pavement specifications. The handling of bituminous sand for paving work is complicated enough without adding the complication of securing a variety of grades of crude material for blending. Also, with additional complication there goes additional cost. Bituminous sands excavated from one sand working will not be likely to give a material that can be made up into a safe and satisfactory sheet paving aggregate. It would, however, be able to produce a sufficiently stable aggregate for sidewalk surfaces. There are many makeshift cinder sidewalks in Edmonton that could be turned into good walks by a surfacing of sheet asphalt. There is a strong demand in the city that something of the sort be done. If the sheet asphalt surfacing of these cinder walks were undertaken, no money would be saved by the use of bituminous sand. On the other hand, if the cinder sidewalks were surfaced by sheet asphalt mixtures made from imported asphalt and mixed in the paving plant, not only would sure results be obtained, but the paving plant equipment which the city possesses would be employed more nearly to capacity, and thereby a reduction in the unit cost of pavement work would be secured.

CONCLUSION

There seems little possibility for concluding otherwise than that the utilization of crude bituminous sand for pavement construction is not practicable. The asphalt plants ordinarily used for the mixing of bituminous pavement aggregates, and possessed by all communities that have built bituminous pavements, are not adaptable to the handling of bituminous sand. Extra and more complicated equipment would have to be acquired. The procedure for mixing suitable paving aggregates from bituminous sand is more complicated than the mixing of them from pure asphalt and clean sand, and it is more difficult to establish a standard procedure and to secure uniform results.

It appears necessary to further conclude that bituminous pavement construction offers no outlet for crude bituminous sand. But it is not necessary to conclude that pavement construction will not offer any outlet for the bitumen which the bituminous sands contain. If it were possible to supply the highway engineer with a separated and properly prepared bituminous sand asphalt, instead of merely the crude bituminous sand, the case would be entirely changed. There would then be no difficulties, such as modified paving plants and changed procedure. It would simply be a case of substituting in the ordinary procedure an asphalt produced at home for one that was formerly imported. If the bitumen can be successfully separated from the bituminous sands, and can be refined into a product equivalent to the asphalt imported for paving work, and at a cheaper price, then pavement construction can be looked to as a substantial outlet for a commercial product obtainable from the bituminous sands.

BITUMINOUS SAND AND THE RURAL ROAD

It was stated in the introduction to this report on the subject of bituminous sands that the solution of the problem of the commercial development of the bituminous sand deposits was two-fold in nature: that it involved the separation of the bitumen from the sand, and then the finding of a real use for the separated bitumen. The efforts of the Industrial Research Department to find a separation process have been described. It now remains to discuss what has been done towards finding a use for the product of the separation process. Enough has been already hinted to indicate that the efforts to this end have been in the direction of prairie rural highway construction.

The earth road or some modification of it will always be the predominating type of prairie rural road. This state of affairs seems inevitable, since earth is the only material which nature has supplied out of which the majority of prairie roads can be built. Those occasional localities which are especially favored by a deposit of gravel can surface some of their roads near the deposit with gravel. Some main roads will become so important that they will be surfaced at great expense with imported materials. But the great mileage of prairie rural road will continue to be built of the soil through which it runs.

The prairie earth road is often a very good road under favorable conditions. But it has one fatal failing: it loses all its stability when it gets wet. An earth road would be a very much more serviceable type of road if its characteristic of turning into a mud road in wet weather could be eliminated. There is considerable hope that this result can be accomplished by the use of bitumen—by the bitumen which can be separated from the bituminous sands.

Laboratory Experiments with Bituminized Earth Mixtures

A series of soil samples were collected and brought to the Industrial Research Department for the purpose of experiment. These samples were taken from roadways, and were chosen to represent the variation of soils from heavy clay to fine sand. A series of test mixtures were made from each soil sample, containing an increasing percentage by weight of crude separated bitumen.* The test samples were prepared by first wetting the soil to a workable state, and then incorporating the calculated weight of bitumen into the wet soil by kneading. The "wet" separated bitumen mixed into the wet soils readily. The wet bituminized soil samples were each placed in a small box, and compacted, the surface being rounded off. The samples were then allowed to dry. The dry bituminized soil samples were tested for resistance against the disintegrating action of water. This was accomplished by exposing the samples to a spray of water. It was found that, in the case of

*At the time of these experiments no large amount of separated bitumen was available. Attempts at separation, however, had produced a limited supply of a crude bitumen containing about 15% of sand and 20% of water.

all the soils except heavy clays, the incorporation of from 5 to 10% of the crude, separated bitumen available for the experiments sufficed to so stabilize the soil sample that it would withstand wetting by the spray of the hose for 15 hours without any tendency to soften or turn into mud. Heavy clay soils required the addition of 15 to 20% of the separated bitumen to accomplish the same result†.

SOME PRACTICAL TESTS OF BITUMINIZED EARTH AGGREGATES

The laboratory trials at stabilizing prairie soils by means of the bitumen separated from the bituminous sand were decidedly encouraging. A practical test of the idea by means of an experimental road section is now needed. Something in this direction was accomplished last fall. Part of the second carload of bituminous sand, purchased by the City of Edmonton for use as sidewalk surfacing material, was used in a trial at stabilizing soil. A quantity of a rather clayey soil from a building excavation in the business section of the city was taken to the city paving plant. The soil was placed in a mortar mixing box, and soaked with water. Bituminous sand was heated in the rotary mixer sufficiently to soften it and break down lumps. Approximately equal volume of wet soil and bituminous sand were placed in the pug mill of the paving plant, and thoroughly mixed into each other. The batches were laid as a stretch of sidewalk on 104th Avenue, immediately east of 95th Street. The mixture was very wet and soft when laid, but dried enough over night to become stiff and fairly hard. It cracked a good deal in drying. The stretch of sidewalk resisted several periods of rainy and slushy weather without turning into mud. It can not be said that it did not soften, however: but it made a vastly better place to walk upon than did the slimy mud that was abundant elsewhere. Analysis showed between 7 and 8% of bitumen in these bituminized soil mixtures.

A continuation of the stretch of bituminized earth sidewalk on 104th Avenue is also of interest in this connection. Portland cement was used to supply extra filler to the sheet-asphalt aggregates prepared from the shipments of bituminous sand. An attempt was made to see if clay soil could be substituted for the portland cement. It was considered that, if wet clay soil were introduced into the sheet-asphalt mixture, the very fine clay particles would be loosened from one another, and be free to disperse into the bitumen of the mixture as individual particles instead of as lumps of clay. If all the water were driven off, the final result would be simply an ordinary sheet-asphalt aggregate with clay instead of portland cement as a filler. But, unfortunately, the

†Two similar sets of experiments were made, using crude low-temperature lignite-tar, and by-product coke-oven coal-tar, instead of the bituminous sand asphalt. The results were quite similar. Neither of these tars showed the bonding action in the soil sample that was shown by the samples into which the bituminous sand bitumen had been incorporated. The coal-tar was hard to mix into the soils; both the bituminous sand bitumen and the lignite-tar mixed very readily. Both these latter bitumens had a high content of water.

action of the mixer was such that the clay had no tendency to mix into the aggregate. It simply balled up and rolled around. The hot bituminous sand sheet-asphalt mix and the wet clay were then transferred to the pug mill and mixed. A number of such batches were prepared, and laid as sidewalk surface on 104th Avenue. These batches differed from those mentioned in the preceding paragraph in that they contained a different proportion of soil to bituminous sand. They were more like sheet-asphalt aggregates that contained a high proportion of clay filler and that had been mixed wet instead of by means of heat. The content of bitumen was between 10 and 11%. The batches were brown in color when laid and rolled into shape on the sidewalk. As they dried they turned black, did not crack, and became very hard and stable. This stretch of sidewalk resisted the action of the rain and the slushy weather without any sign of softening. It is not unlikely that the sidewalk obtained by these wet-mixed aggregates will prove to be the most satisfactory sidewalk laid from the second carload of bituminous sand.

Conclusion

Bituminized earth aggregates can be of two types or natures, depending on the quantity of bitumen that is incorporated into them. When a small percentage of a bitumen, such as that separated from the bituminous sand, is incorporated into a wet soil, the bitumen apparently disperses through the soil mass, and spreads onto the surfaces of the soil particles. When the bituminized soil dries, it still has most of the characteristics of the original soil. It is not softened by heat, and, if allowed to dry in compact form, the lumps are hard, and break as if composed of untreated soil. The great difference between the bituminized soil and the original soil is in their behavior towards water. A lump of the original soil will soak up water readily and soften; the bituminized soil tends to shed water, and to keep it from penetrating the mass. As the percentage of bitumen incorporated into the soil is increased, the condition of each soil particle being merely thinly filmed over with bitumen is passed, and an excess of bitumen is contained in the mixture. If the bituminized soil is then compacted, it presses into a solid, dense mass. Such a bituminized soil has departed from the nature of the original soil. It will soften on application of heat, and will flow and mould under pressure. It is also quite impervious to water. These two types of bituminized earth aggregate are fairly well illustrated by the two aggregates prepared from the bituminous sand, and laid on 104th Avenue. These two types of bituminized soil aggregate suggest a procedure for road construction, consisting in providing a rigid and water-resisting foundation of soil containing a small percentage of bitumen, and then capping this foundation by a surface layer of soil made dense and impervious to water by the incorporation of a sufficiently large percentage of bitumen.

It is the intention of the Industrial Research Department to

build, during 1923, a stretch of experimental bituminized earth road. Mention has been made of a stock of about 100 tons of bituminous sand on hand for a try-out of a separation plant. If the plant works successfully, a supply of some 15 to 20 tons of separated bitumen will be secured. This would be enough to construct a considerable stretch of roadway.

The idea of bituminized earth roads is not new. Oiled earth roads and bituminized earth roads have been constructed in various parts of the United States with varying degrees of success. The subject of bituminized earth aggregates has been given some study by the U. S. Bureau of Roads at Washington. In the light of what has been found out elsewhere, and of what we are finding out, it is hoped that the bituminized earth road can be adapted to our own particular conditions, and that it will prove to be a practical solution of the rural highway construction problem of Alberta.

SUMMARY

It has been the purpose of the foregoing report to give an account of the activities of the Industrial Research Department towards the solution of the problem of the commercial development of the bituminous sand deposits of Alberta. In keeping with the conception of the two-fold nature of the problem, the activities of the Department have been directed towards the devising of a scheme for the separation of the bitumen content of the bituminous sands from the large amount of sand and mineral matter with which it is associated, and then the finding of some use of wide application for the bitumen, when separated. There is good reason to believe that a practical method of separation has been found; and encouraging indications have been observed that bituminized earth rural road construction will form an outlet for the utilization of the bitumen so separated. A plant is in process of being assembled for testing out the separation process on a sufficiently large scale to determine its practicability. Plans for the coming year include an experimental road construction project to ascertain whether earth roads bituminized by bituminous sand bitumen will meet the requirements of rural roads in Alberta. It is hoped that in the Fourth Annual Report of the Scientific and Industrial Research Council of Alberta a satisfactory account can be given of a practical and economical method of bituminous sand separation, and of an equally satisfactory procedure for employing the bituminous sand bitumen to meet the rural highway construction difficulties of the prairie provinces.

COAL SAMPLES AND ANALYSES

Analyses of two classes of coal samples are given in the following tables. The first class consists of samples taken from the carload consignments received for testing at the laboratories of the University. This coal was taken at the mine by a provincial inspector of mines, and represents the commercial output of the mine at the time. Approximately one ton was cut out from each carload lot (about 30 tons) by taking a shovelful of coal at regular intervals as the coal was unloaded from the carts at the University. This was then cut down in the Sturtevant crusher-sampler as described under sampling on page 12. The coning and quartering method used last year was superseded in May of this year.

The second class of samples are mine face, or channel, samples taken from a working face of a mine by provincial mine inspectors to represent the output. The method adopted is that described in the First Annual Report of the Council, pages 17 to 19. It should be noted that the sampler is instructed to exclude from his sample all partings, bone coal, slate, etc., which in his judgment would be rejected by the miner, and not included in the commercial shipments of the mine. This procedure tends to result in mine samples which are cleaner than the commercial shipments, although this is not always the case. The inspector takes one or more samples from each mine according to its output. In the larger mines he takes his samples in different working areas throughout the mine in such a way as to represent as closely as possible the average product shipped.

The mine inspectors took a number of special samples from mine bins and tipples for comparison with the regular channel samples. These were analysed, but the analyses are not included in the tables.

A complete proximate analysis was made of all the samples submitted. The carload samples and samples from the Penn mine were analyzed in the Industrial Research Department. Other samples were analyzed for the Provincial Mines Branch by Mr. J. A. Kelso, Provincial Analyst. In compiling the tables, the samples are arranged geographically, classified according to the areas in which they occur. A specific name is given each mine, as well as the number of the mine in the records of the Provincial Mines Branch. When more than one regular sample has been taken from a mine at the same time, the results are averaged, and only the average analysis is given. The number of samples represented by this average is stated. All samples were air-dried by exposure to the air in the laboratory until the loss in weight became negligible. The percentage moisture loss during air-drying is stated. The other analyses are those obtained on the air-dry coal. The

fuel ratio quoted for each sample is the ratio obtained by dividing its percentage of fixed carbon by that of its volatile matter. This ratio gives an indication of the nature of the coal.

The table of typical analyses from each of the principal coal-producing areas of the province was prepared from the analyses published by the Council during the past three years. The loss on air-drying gives the percentage of moisture lost when the original sample, as taken from the mine and shipped in a sealed container, is air-dried. All other analyses are on the air-dry coal. It is hoped to replace this table later on by one based on a larger number of samples, but it will serve for the present, at least, to indicate the variations in the nature of the coals from the different areas. The tables were compiled by Mr. J. B. Coghill.

	Jasper Park Area	Saunders Creek Area
No. and Name of Mine..	No. 429, Brule	No. 823, Harlech
Name of Operator..........	Blue Diamond Coal Co., Ltd.	Harlech Coal Co., Ltd.
Location of Mine..............	Brule Mines	Harlech
Loss on Air Drying........%	1.2	1.3
Proximate Analysis: (air dry coal)		
Moisture......................%	1.9	5.3
Ash...............................%	17.3	9.7
Volatile Matter............%	18.1	32.6
Fixed Carbon...............%	62.7	52.4
Sulphur ....%	....	0.5
Calorific Value, gross, ...B.T.U. per lb.	12,460	11,390
Fuel Ratio..........................	3.5	1.6
Kind of Sample................	Car load commercial sample	Average of 3 channel samples
Sample taken by................	W. Shaw	J. A. Richards
Date of Sampling..............	December, 1921	October, 1922

	Yellowhead Pass Area	Drumheller Area
No. and Name of Mine....	No. 1002, Coal Valley (stripping pit)	No. 402, Monarch
Name of Operator............	Coal Valley Mining Co.	North American Collieries, Ltd.
Location of Mine..............	Mile 48, Lovett Branch	Nacmine
Loss on Air Drying........%	6.2	9.4
Proximate Analysis: (air dry coal)		
Moisture......................%	2.3	6.9
Ash...............................%	9.0	10.6
Volatile Matter............%	35.8	34.6
Fixed Carbon...............%	52.9	47.9
Sulphur ....%	0.5	....
Calorific Value, gross, ...B.T.U. per lb.	11,800	10,746
Fuel Ratio..........................	1.5	1.4
Kind of Sample................	Channel sample	Car load commercial sample
Sample taken by..............	T. Horne	D. Shanks
Date of Sampling..............	December, 1922	January, 1922

	Big Valley Area	
No. and Name of Mine....	No. 364, Big Valley	
Name of Operator............	Big Valley Collieries, Ltd.	
Location of Mine............	Big Valley, Alta.	
Loss on Air Drying........%	5.9	*This sample of coal was screened over a 1½-in. bar screen, as it was being loaded into the car, this being the usual practice at this mine for R.O.M. shipments.
Proximate Analysis: (air dry coal)		
Moisture........................%	16.0	
Ash................................%	12.5	
Volatile Matter............%	30.3	
Fixed Carbon...............%	41.2	
Sulphur ....%	....	
Calorific Value, gross, ...B.T.U. per lb.	8,900	
Fuel Ratio..........................	1.35	
Kind of Sample................	Car load commercial sample*	
Sample taken by..............	M. Cranston	
Date of Sampling..............	October, 1922	

	Pembina-Wabamun Area	Edmonton-Clover Bar Area
No. and Name of Mine....	No. 419, Lakeside	No. 632, Penn
Name of Operator............	Lakeside Coals, Ltd.	Crown Coal Co., Ltd.
Location of Mine............	Wabamun	Edmonton
Loss on Air Drying........%	7.5	8.3
Proximate Analysis: (air dry coal)		
Moisture........................%	14.0	17.7
Ash................................%	8.0	7.1
Volatile Matter............%	32.6	30.5
Fixed Carbon...............%	45.4	44.7
Sulphur ....%	0.3	....
Calorific Value, gross, ...B.T.U. per lb.	9,750	9,510
Fuel Ratio..........................	1.4	1.45
Kind of Sample................	Average of 3 channel samples	Average of 5 channel samples
Sample taken by..............	W. Shaw	W. Shaw
Date of Sampling..............	November, 1922	December, 1922

TYPICAL ANALYSES FROM ALBERTA COAL AREAS

AREA	Crow's Nest Pass	Canmore, Banff	Brazeau	Mountain Park	Jasper Park	Saunders Creek	Yellowhead Pass	Lethbridge, McGrath	Medicine Hat, Redcliffe
Loss on Air-Drying %	1.6	0.5	0.5	2.1	1.6	2.4	5.1	1.5	6.8
ANALYSIS OF AIR-DRY COAL									
Proximate:									
Moisture %	0.5	0.4	0.3	0.1	0.6	5.3	2.9	8.5	17.9
Ash %	15.4	9.3	11.3	14.9	17.6	8.9	10.7	9.8	9.0
Volatile Matter %	25.5	12.8	16.6	25.7	17.4	32.5	34.7	33.6	32.7
Fixed Carbon %	58.6	77.5	71.8	59.3	64.4	53.3	51.7	48.1	40.4
Ultimate:									
Carbon %	71.1	82.0	80.6	......	72.0	......	......	65.0	......
Hydrogen %	4.0	4.1	3.9	......	3.7	......	......	4.7	......
Ash %	15.4	9.3	11.3	......	17.6	......	......	9.8	......
Sulphur %	0.6	0.5	0.3	......	0.4	......	......	0.5	......
Nitrogen %	1.1	1.3	1.2	......	1.3	......	......	1.8	......
Oxygen %	7.8	2.8	2.7	......	5.0	......	......	18.2	......
Calorific Value, gross, B.T.U. per lb.	12,590	13,800	13,560	12,870	12,550	11,400	11,600	10,950	8,860
Fuel Ratio, (F.C./V.M.)	2.3	6.1	4.3	2.3	3.7	1.65	1.5	1.45	1.25
Carbon/Hydrogen Ratio	17.8	20.0	20.7	......	19.5	......	......	13.8	......

TYPICAL ANALYSES FROM ALBERTA COAL AREAS

AREA	Drumheller	Big Valley, Trochu, &c.	Pembina, Wabamun	Taber, Bow Island	Lacombe	Camrose, Battle R.	Tofield	Edmonton, Clover Bar	Cardiff, Namao
Loss on Air-Drying %	3.3	5.9	4.5	1.1	8.6	6.8	9.0	6.3	5.9
ANALYSIS OF AIR-DRY COAL									
Proximate:									
Moisture %	12.9	16.0	15.6	12.5	18.3	19.0	17.6	19.0	19.0
Ash %	7.8	12.5	9.7	9.8	7.9	6.8	5.4	7.5	7.0
Volatile Matter %	34.6	30.3	31.0	32.5	32.1	33.1	32.7	31.1	32.7
Fixed Carbon %	44.7	41.2	43.7	45.2	41.7	41.1	44.3	42.4	41.3
Ultimate:									
Carbon %	59.5	....	54.0	....	54.0	....	....	53.8	53.4
Hydrogen %	5.2	....	4.9	....	5.5	....	....	5.7	5.8
Ash %	7.8	....	9.7	....	7.9	....	....	7.5	7.0
Sulphur %	0.4	....	0.3	....	0.6	....	....	0.3	0.4
Nitrogen %	1.3	....	0.7	....	1.0	....	....	1.2	1.1
Oxygen %	25.8	....	30.4	....	31.0	....	....	31.5	32.3
Calorific Value, gross, B.T.U. per lb.	10,040	8,900	9,280	10,060	9,010	9,110	9,350	9,220	8,930
Fuel Ratio, (F.C./V.M.)	1.3	1.35	1.4	1.4	1.3	1.25	1.35	1.35	1.25
Carbon/Hydrogen Ratio	11.4	....	11.0	....	9.8	....	....	9.4	9.2

LIST OF PUBLICATIONS

ANNUAL REPORTS OF THE SCIENTIFIC AND INDUSTRIAL RESEARCH COUNCIL OF ALBERTA

Report No. 3 (for the calendar year 1920) ; pp. 36.

Report No. 5 (1921) ; pp. 86.—Reviews of the work done during 1921 under the auspices of the Research Council. This includes:—the sampling, screening, storage and carbonization of Alberta coals, and their use in boilers; tests on household furnaces; geological reconnaissance in Alberta; the Athabaska district bitumious sand and its commercial development; road materials; forest products; salt at Fort McMurray; analyses of coal samples taken by the Mines Branch of the province during the year.

ANNUAL REPORTS ON THE MINERAL RESOURCES OF ALBERTA

By Dr. J. A. Allan, Professor of Geology, University of Alberta.

Report No. 1 (1919) ; pp. 104.—A summary of information collected with regard to the mineral resources of Alberta.

Report No. 2 (1920) ; pp; 138+14.—Supplements the information contained in Report No. 1.

Report No. 4 (1921), GEOLOGY OF THE DRUMHELLER COAL FIELD, ALBERTA; pp. 72, and 6-colour map (Serial No. 1). Price $1.00.

Report No. 6 (1922, Pt. I.), GEOLOGY OF THE SAUNDERS CREEK AND NORDEGG COAL BASINS, ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 76, and 2-colour map (Serial No. 2.). A preliminary report on the stratigraphy of the coal measures mined along the Brazeau Branch of the Canadian National Railways.

Report No. 7 (1922, Pt. II.), AN OCCURRENCE OF IRON ON THE NORTH SHORE OF LAKE ATHABASKA, by J. A. Allan and A. E. Cameron; pp. 40, two maps (Serial Nos. 3 & 4).—Chapter I. deals with the association of iron minerals in pre-Cambrian rocks in the vicinity of Fishhook Bay. Chapter II. deals with the problems of transportation, smelting and markets.